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SIGNIFICANCE OF ABBREVIATIONS MOST FREQUENTLY ENCOUNTERED IN SOVIET PERIODICALS

FIAN	Phys. Inst. Acad. Sci. USSR.
GDI	Water Power Inst.
GITI	State Sci.-Tech. Press
GITTL	State Tech. and Theor. Lit. Press
GONTI	State United Sci.-Tech. Press
Gosenergoizdat	State Power Press
Goskhimizdat	State Chem. Press
GOST	All-Union State Standard
GTTI	State Tech. and Theor. Lit. Press
IL	Foreign Lit. Press
ISN (Izd. Sov. Nauk)	Soviet Science Press
Izd. AN SSSR	Acad. Sci. USSR Press
Izd. MGU	Moscow State Univ. Press
LEIIZhT	Leningrad Power Inst. of Railroad Engineering
LET	Leningrad Elec. Engr. School
LETI	Leningrad Electrotechnical Inst.
LETIIZhT	Leningrad Electrical Engineering Research Inst. of Railroad Engr.
Mashgiz	State Sci.-Tech. Press for Machine Construction Lit.
MEP	Ministry of Electrical Industry
MES	Ministry of Electrical Power Plants
MESEP	Ministry of Electrical Power Plants and the Electrical Industry
MGU	Moscow State Univ.
MKhTI	Moscow Inst. Chem. Tech.
MOPI	Moscow Regional Pedagogical Inst.
MSP	Ministry of Industrial Construction
NII ZVUKSZAPIOI	Scientific Research Inst. of Sound Recording
NIKFI	Sci. Inst. of Modern Motion Picture Photography
ONTI	United Sci.-Tech. Press
OTI	Division of Technical Information
OTN	Div. Tech. Sci.
Stroiizdat	Construction Press
TOE	Association of Power Engineers
TsKTI	Central Research Inst. for Boilers and Turbines
TsNIEL	Central Scientific Research Elec. Engr. Lab.
TsNIEL-MES	Central Scientific Research Elec. Engr. Lab.—Ministry of Electric Power Plants
TsVTI	Central Office of Economic Information
UF	Ural Branch
VIESKh	All-Union Inst. of Rural Elec. Power Stations
VNIIM	All-Union Scientific Research Inst. of Meteorology
VNIIZhDT	All-Union Scientific Research Inst. of Railroad Engineering
VTI	All-Union Thermotech. Inst.
VZEI	All-Union Power Correspondence Inst.

Note: Abbreviations not on this list and not explained in the translation have been transliterated, no further information about their significance being available to us. — Publisher.

THE OXIDATION POTENTIAL OF BICHROMATE

B. V. Ptitsyn and V. F. Petrov

The great practical value of bichromates as oxidizing agents and their lack of study in this respect led us to believe that a more detailed quantitative characterization should be given to the oxidative force shown by bichromate solutions under various conditions.

As is known, the end products of bichromate reduction under ordinary conditions are compounds of trivalent chromium.

If it is assumed that a true thermodynamic equilibrium exists between the ions $Cr_2O_7^{2-}$ and Cr^{3+}, expressed by the equation;

$$Cr_2O_7^{2-} + 14H^+ + 6e \rightleftarrows 2Cr^{3+} + 7H_2O, \tag{1}$$

then the potential of the bichromate solution should be determined by the equation:

$$E = E_0 + \frac{RT}{6F} \ln \frac{a_{Cr_2O_7^{2-}} \cdot a_{H^+}^{14}}{a_{Cr^{3+}}^2}. \tag{2}$$

However, the reversibility of this process can be considered not only as being unproved, but based on both the literature [1-3] and our own data, it can confidently be stated that the transition of the $Cr_2O_7^{2-}$ ions into Cr^{3+} ions proceeds in several successive stages.

There fails to be any reliable information at the present time relative to either the dependence of the oxidation potential of bichromate on the pH or the influence shown by the nature of the acid on this potential. The question as to the influence exerted by trivalent chromium ions on the potential of bichromate solution also remains obscure.

A number of authors [4-7] mention the strange form of the curve obtained in the titration of bichromate with a ferrous salt. Some of these authors [4, 6] believe that the first stage in the reduction of sexivalent chromium is the formation of quinquevalent chromium compounds.

A. M. Zanko and V. F. Stefanovsky [3], who made a special study of the mechanism of bichromate reduction, also believe that it is possible for intermediate oxidation forms to exist in the solutions and first of all the quinquevalent chromium, and consequently that the potential of the system will be determined by the ratio of the activities of the compounds of sexivalent chromium and the compounds of any intermediate oxidation forms.

King and Neptune [8] studied the light absorption of $Cr(ClO_4)_3 + HClO_4$ and $Na_2Cr_2O_7 + HClO_4$ solutions, both separately and in admixture with each other, at wavelengths of 290 and 700 mμ and found that the solutions, containing Cr^{3+} and Cr^{6+} show enhanced light absorption. They explain this circumstance as due to the formation of unstable $CrCrO_4^+$ and $CrCrO_4H^{2+}$ complexes, containing the oxygen bridge $Cr^{3+}-O-Cr^{6+}$. Quite a few examples of similar complexes, containing the same metal in different degrees of oxidation, are known. To the systems

Cu^{+}–Cl–Cu^{2+} and Fe^{2+}–Cl–Fe^{3+} mentioned by the indicated authors can be added the Pt^{2+} – Pt^{4+} compounds, for example Pt^{2+}–Br–Pt^{4+}, studied in detail by A. A. Grinberg and F. M. Filinov [9]. In all of these cases bonding is realized by oxidation-reduction electron exchange, and it is completely natural that such combinations represent thermodynamically reversible oxidation-reduction systems. The Cr^{3+} – Cr^{6+} system is completely lacking in this property, for which reason it seems to us that the manner in which the authors treated their obtained results evokes definite doubt.

It is obvious that the question of the first reduction stage of sexivalent chromium is of primary importance for the derivation of the equation expressing the oxidation properties of bichromate and the magnitude of its potential. Consequently, we first checked the literature data on the mechanism for the reduction of bichromate with Mohr's salt and on the influence shown by trivalent chromium on the oxidation potential of bichromate solution, and then we made a detailed study of the dependence of the oxidation potential of bichromate on the pH in the presence of perchloric, sulfuric, nitric and acetic acids. Hydrochloric acid was not used for the reason that it shows noticeable reduction properties.

Starting Compounds

Mohr's salt and potassium bichromate were recrystallized three times.

The purified chromium nitrate crystals were dried in a stream of dry air at 32-33°. It was assumed that the composition of the obtained violet crystals corresponds to the formula $Cr(NO_3)_3 \cdot 9H_2O$. The titer of the $Cr(NO_3)_3$ solutions were found gravimetrically. The solutions of chromic acid were prepared from Kahlbaum chromic anhydride. Its amount was controlled by titration with sodium thiosulfate solution. The solutions of perchloric, nitric, sulfuric and acetic acids were prepared from concentrated, chemically pure acid in the usual manner. All of the solutions of the acids were checked for the absence of reducing agents.

The Mechanism of Bichromate Reduction

To check the literature data we ran potentiometric titrations on sulfuric acid solutions of potassium bichromate with solutions of Mohr's salt. The concentrations of the potassium bichromate solutions were: 1.0 N, 0.1102N, 0.05N and 0.0107N. The concentrations of the Mohr's salt solutions approximately correspond to the concentrations of the bichromate solutions.

The obtained results coincide with the literature data, i.e., in the first period of titrating potassium bichromate solutions the magnitude of the oxidation potential increases, and then falls.

An increase in the potential at the start of titration indicates that chromium compounds with an intermediate valency are formed in the first stage of the process, being stronger oxidizing agents than bichromate itself. The maximum on the titration curves corresponds to the number of milliliters of Mohr's salt solution needed to reduce sexivalent chromium to the quadrivalent stage. It can be assumed that the first stage for the transition of sexivalent chromium to the quinquevalent stage does not appear on the curve for the reason that their oxidation potentials lie close to each other. To be sure, the obtained data are not sufficient to arrive at a final decision as to the nature of the processes that take place in the reduction of sexivalent chromium. Undoubtedly, these processes are complex and require time, as evidenced only by the fact that the potential is established slowly, in approximately 2-3 hours after adding an alternating portion of Mohr's salt solution. If time is not allowed for the final establishment of the potential and if the titrated solution is stirred slightly, then a maximum on the titration curve is completely absent. It is characteristic that in measure with increase in the concentrations of the potassium bichromate solutions the maximum on the titration curve becomes less sharp. For a one normal bichromate solution the experimental titration curve approximates the theoretical curve, calculated on the assumption that the bichromate is reduced by bivalent iron ions to trivalent chromium.

The Influence of Trivalent Chromium on the Oxidation Potential of Bichromate Solution

The existing literature data relative to the influence of trivalent chromium on the oxidation potential of bichromate solution are laconic and in part contradictory. According to the data of some authors the ions of trivalent chromium in general do not affect the oxidation potential of bichromate [1], while according to other data they reduce it [10].

For the purpose of checking the literature data we measured the oxidation potential of potassium bichromate solutions containing various concentrations of Cr^{3+} ions at various pH values.

The usual potentiometric apparatus with a mirror galvanometer was used for the measurements, which were made at 18 ± 0.1° and with constant stirring (the intensity of stirring was maintained constant in all cases). A smooth platinum electrode served as the indicator electrode. For greater accuracy three electrodes were simultaneously used in all of the experiments, and their average reading was calculated after the potential had become fixed. Glass electrodes were used for the pH measurements. The readings of the platinum and glass electrodes were taken simultaneously. The experimental results are given in the table. In all cases the values of the oxidation potentials are given in millivolts with respect to the hydrogen electrode.

TABLE

Influence of Trivalent Chromium on the Oxidation Potential of Potassium Bichromate Solution at Various pH Values.

Expt. Nos.	$[Cr_2O_7^{2-}] : [Cr^{3+}]^2$	HNO_3 (M.)	pH	E (mV)
1	10.0	1.01	0.15	1219
2	1.0	1.01	0.15	1218
3	0.1	1.01	0.15	1219
4	Without Cr^{3+}	1.01	0.15	1217
5	10.0	0.10	0.90	1038
6	1.0	0.10	0.90	1037
7	0.1	0.10	0.90	1038
8	Without Cr_3^{+}	0.10	0.91	1037

Remarks: The pH values were calculated in Expts. 1-4, and measured in Expts. 5-8.

The experimental results show an agreement of the oxidation potential values of potassium bichromate solutions at the same pH values and different concentrations of trivalent chromium.

On the basis of the obtained data it can very definitely be concluded that trivalent chromium does not show an influence on the oxidation potential of bichromate solution. Consequently, Equation [1] cannot serve to depict the process that determines the magnitude of the potential on a platinum electrode for the system Cr^{6+}–Cr^{3+}.

Dependence of the Oxidation Potential of Bichromate on the pH in the Presence of Various Acids

Since the presence of trivalent chromium ions does not affect the oxidation potential of bichromate solution, the determination of the relationship between the oxidation potential and the pH was made in $K_2Cr_2O_7$ solutions without the additions of trivalent chromium salts.

The influence of the following acids was studied: $HClO_4$, H_2SO_4, HNO_3 and CH_3COOH.

The amount of each acid added to the bichromate solution was such as to make the pH of the solution as nearly close to zero as possible, and in the case of acetic acid as low as possible. Variation of the pH was achieved by adding sodium hydroxide solution of known molarity in such manner that the pH values in the different experiments were as close as possible to each other.

The pH values of the solutions were measured with the aid of ordinary glass electrodes, and parallel with this the oxidation-reduction potentials in the same solutions were measured with the aid of platinum electrodes.

The experimental data showing the relationship that exists between the oxidation potential of potassium bichromate solution and pH are plotted in Fig. 1. In these experiments the concentration of the bichromate solutions was 1/30M In all cases 1N alkali solutions were taken. Instead of potassium bichromate solution a solution of chromic acid was used in the experiments with perchloric acid. The measurements made on the $H_2Cr_2O_7$

solution revealed that in alkaline medium the curve practically merges with the curve for pure potassium bichromate solution.

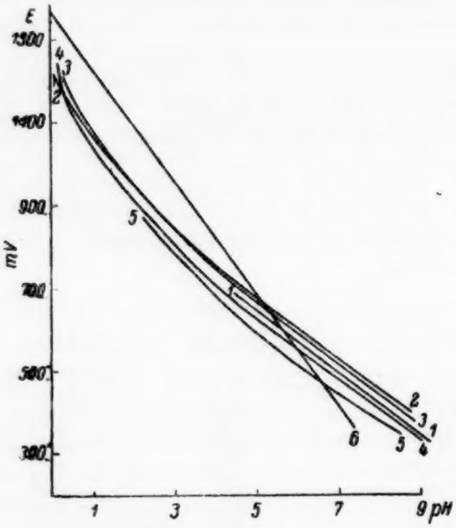

Fig. 1. Relationship between the oxidation potential of potassium bichromate solutions and the pH in the presence of various acids.
1) $K_2Cr_2O_7$ solution, 2) $H_2Cr_2O_7$ + $HClO$ solution, 3) $K_2Cr_2O_7$ + H_2SO_4 solution, 4) $K_2Cr_2O_7$ + HNO_3 solution, 5) $K_2Cr_3O_7$ + CH_3COOH solution, 6) theoretical (from Equation [2]).

The following conclusions can be made from an examination of the curves showing the relationship between the oxidation potential of potassium bichromate solution in various acids and the pH in the presence of NaOH.

1. Not one of the curves coincides with the theoretical curve, which once more supports the inapplicability of Equation (2).

2. The curves for the different acids show approximately parallel arrangement. They are somewhat steeper in the acid region than in the alkaline.

3. The oxidation potential value of potassium bichromate solution depends on the nature of the acid in which it is dissolved, which apparently is explained by the different tendency shown by the ions of these acids for complex formation.

4. As the pH approaches zero the potentials in all of the strong acids strive to assume the same value. For pH > 7 the oxidation potentials of potassium bichromate solutions in all of the acids are higher than those calculated with the aid of equation (2).

At pH ≈ 9 the bichromate converts to the chromate.

The character of the experimental curves leads to the completely natural assumption that in different pH regions the chromium compound exists in the form of different ions, i.e., that we should take into consideration the hydrolytic equilibria that are present. We will assume that the first reduction stage of sexivalent chromium compounds are quinquevalent chromium compounds, and we will further assume the existence in nitric acid solutions of nitrochromic acid $H[CrO_3NO_3]$, similar to the chlorochromic acid $H[CrO_3Cl]$, formed in hydrochloric acid solutions of bichromate. In such case the following equilibria can arise in aqueous bichromate solutions, containing quinquevalent chromium compounds:

1) For Cr^{6+}:

$$H[CrO_3NO_3] + H_2O \rightleftarrows H_2CrO_4 + HNO_3,$$
$$2H_2CrO_4 \rightleftarrows H_2Cr_2O_7 + H_2O.$$

2) For Cr^{5+}:

$$CrO(NO_3)_3 + H_2O \rightleftarrows CrO_2NO_3 + 2HNO_3,$$
$$CrO_2NO_3 + H_2O \rightleftarrows HCrO_3 + HNO_3,$$
$$HCrO_3 + H_2O \rightleftarrows H_3CrO_4.$$

From this it follows that the oxidation potential of bichromate at different pH values can be determined by the following processes:

$$[CrO_3NO_3]^- + 4H^+ + \bar{e} \rightleftarrows CrO^{3+} + NO_3^- + 2H_2O,$$
$$E = E_0 + 58\log[H^+]^4 = E_0 - 232 \text{ pH}; \tag{3}$$

$$[CrO_3NO_3]^- + 2H^+ + \bar{e} \rightleftarrows CrO_2^+ + NO_3^- + H_2O,$$
$$E = E_0 + 58\log[H^+]^2 = E_0 - 116 \text{ pH}; \tag{4}$$

$$HCrO_4^- + H^+ + \bar{e} \rightleftarrows CrO_3^- + H_2O,$$
$$E = E_0 + 58\log[H^+] = E_0 - 58 \text{ pH}; \tag{5}$$

$$CrO_4^{2-} + \bar{e} \rightleftarrows CrO_4^{3-}. \tag{6}$$

Since we do not know the hydrolytic equilibrium constants of sexi- and quinquevalent chromium compounds, we can say nothing as to which pH regions will correspond to the various electrochemical equations, and consequently we cannot construct the theoretical curve showing the relationship between the oxidation potential of bichromate and the pH. However, through the following considerations we can determine if there is a grain of truth in these assumptions.

We will examine the experimentally found relationship existing between the oxidation potential of bichromate and the pH in the presence of the NO_3^- ion. We will assume that in the strongly acid region, beginning from pH = 0, for which E = 1240 mv, Equation (3), depicted by the straight line I (Fig. 2), is valid. We see that with such an assumption the theoretical straight line I practically coincides with the experimental curve in the pH region from 0 to 0.8, and deviates from it at higher pH values, evidently due to the fact that at pH > 1 the process depicted by Equation (4) (straight line II) begins to predominate. The transition of bichromate into chromate occurs at pH ≈ 9 and E = 375 mv. It is natural to assume that at pH values close to 9 and lower the dependence of E on pH will be depicted by Equation (5) (straight line III). If pH 8 and E = 430 mv is taken as the initial point of this straight line, then straight lines II and III intersect at pH 4.35. From this it can be concluded that the process depicted by Equation (4) predominates in the pH region from 1 to 4, and that process (5) predominates in the pH region from 4 to 8. At pH > 9 Equation (6) becomes operative, in accord with which E is independent of the pH.

If a curve is drawn on the basis of these four straight lines (Curve 2 in Fig. 2), we see that it shows satisfactory agreement with the experimentally found Curve 1.

We obtain a complete answer in the lack of basis and artificial nature of such constructions, and primarily we are inclined to consider all of these deliberations as a stimulus for the quantitative study of the hydrolysis processes of sexi- and quinquevalent chromium compounds. But still it must be acknowledged that this approach, although extremely imperfect, is the first attempt made to explain the peculiar course of the relationship between

the oxidation potential of bichromate and the pH and to cast some light on the behavior of bichromate as an oxidizing agent.

It is obvious that it is impossible to make any conclusions from the obtained values of the potentials as to the normal oxidation shown by a system in which bichromate is the oxidizing agent, for we don't know which system is being discussed, i.e., which chromium compound is functioning in it as a reducing agent. The validity of the calculations made by us for the theoretical curve should be demonstrated by measuring the potential of the system bichromate – Cr^{3+} compound and the corresponding hydrolysis constants.

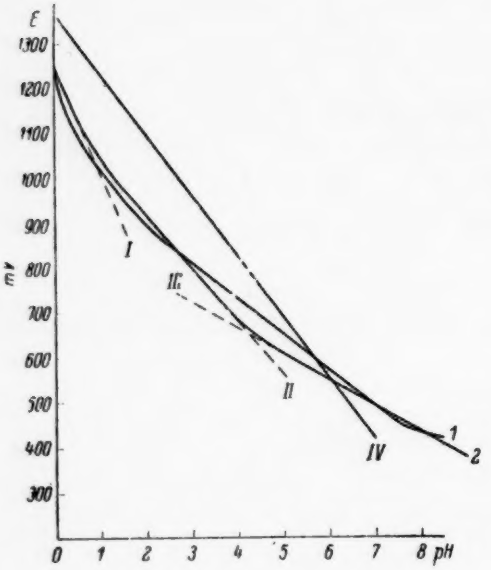

Fig. 2. Relationship between the oxidation potential of the solution $K_2Cr_2O_7$ + HNO_3 and the pH. I) Calculated by Equation (3), II) calculated by Equation (4), III) calculated by Equation (5), IV) calculated by Equation (2), 1) experimental, 2) theoretical.

The potentials measured by us only make it possible to establish the magnitude of the bichromate potential at pH = 0. Extrapolating the values of the bichromate potentials in H_2SO_4 and HNO_3 solutions and the values of the $H_2Cr_2O_7$ potentials in $HClO_4$ solutions to pH = 0, we obtain E = 1240 mv, i.e., a value that is 120 mv smaller than the value 1360 mv, taken at the present time as the normal potential of bichromate.

SUMMARY

1. The reduction of sexivalent chromium to trivalent chromium is not direct, but proceeds in stages with the formation of chromium compounds of intermediate valency, in which connection quinquevalent chromium compounds are in all probability formed in the first stage.

2. It can be considered as firmly established that trivalent chromium ions fail to exert an influence on the oxidation potential of bichromate solution and that a direct equilibrium, depicted by the equation:

$$Cr_2O_7^{2-} + 14H^+ + 6\bar{e} \rightleftarrows 2Cr^{3+} + 7H_2O$$

fails to exist.

3. A study of the relationship between the oxidation potential of bichromate and pH in the presence of various acids revealed that in all cases the theoretical straight line, calculated on the basis of Equation (2), in no way reflects a true picture of the situation. These relationships are depicted by parallel curves, showing that a reduction in the oxidation potential of bichromate with increase in the pH proceeds slower the higher the pH. The nature of the acid shows essential significance. At equal pH values the value of the oxidation potential of bichromate, with rare exceptions, decreases in the following order:

$$HClO_4 > H_2SO_4 > HNO_3 > CH_3COOH.$$

4. A theory was expressed as to the nature of the processes that determine the relationship between the

oxidation potential of bichromate and the pH, and a theoretical curve $E = \underline{f}$ (pH) was calculated. The validity of this theory should be demonstrated by measuring the oxidation potential of the system $Cr^{6+} - Cr^{5+}$ at various pH values and by determining the hydrolytic equilibrium constants of the compounds of Cr^{6+} and Cr^{5+}.

5. On the average the oxidation potential of bichromate in H_2SO_4 and HNO_3 solutions and of $H_2Cr_2O_7$ in $HClO_4$ solution at pH = 0 is equal to 1240 mv.

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STUDY OF METASTABLE EQUILIBRIA BETWEEN LIQUID PHASES; VI.

I. L. Krupatkin

In previous communications [1-4] we presented the results of studying the metastable equilibria existing between two liquid phases in ternary systems and examined the resultant consequences. It was experimentally shown that in the metastable liquid state in ternary systems there are present the same basic forms of two-phase equilibria as exist in them in the stable liquid state. It can be postulated that in the metastable state in ternary systems it should be possible to realize equilibrium of three liquid phases, since this situation prevails in them in the stable state. A stable three-phase liquid equilibrium in ternary systems was discovered in 1887 [5]. Further study of this phenomenon led at the start to a development of the isothermal schemes for its formation [6-8], and then to an elucidation of the polythermal scheme for its origin and changes [9]. As a result, it becomes necessary experimentally to elucidate the very possibility of realizing a metastable three-phase liquid equilibrium in ternary systems, and in case of a satisfactory solution to this problem, to determine the degree of applicability of the indicated polythermal scheme to its origin. To obtain an experimental solution to these questions we selected the ternary system salicylic acid-water- benzine.

EXPERIMENTAL

We took the following reagents for our work: c.p. salicyclic acid with m.p. 155°, twice-distilled water, and the benzine fraction boiling in the range 90-120°. Equilibrium between two and between three liquid phases was studied by the visualpolythermal method of V. F Alekseev [10]. The starting substances were heated in sealted glass ampuls in an oil thermostat. The crystallization of the mixtures was studied in these ampuls; in this connection needlelike crystals of salicylic acid formed at the boundary of two liquid layers.

The ternary system salicyclic acid-water-benzine contains the following binary systems.

The System Salicylic Acid-Water was studied by V. F. Alekseev [11] by the method of fusion and stratification. Metastable equilibrium between two liquid phases was revealed in it. The upper critical point on the equilibrium curve lies at 89.1° and corresponds to 32% salicylic acid. Above the stratification curve the crystallization curve possesses a nearly horizontal portion at about 105°, stretching from 20 to 60% salicylic acid.

System Water-Benzine The mutual solubility of water and benzine was studied by a number of authors [12]. At temperatures up to 100° it is on the average several hundredths of a percent, and from 100 to 200° it is on the average several tenths of a percent. The small value of the mutual solubility and its increase with rise in temperature show that a stable equilibrium between two liquid phases with a very highly situated upper critical point is present in the system. The advantages and disadvantages of operating with benzine, instead of with individual hydrocarbons, has already been discussed earlier [13].

The System Salicylic Acid-Benzine was investigated by the fusion method in the present study. The obtained numerical data are collected in Table 1 and plotted in Fig. 1. As Fig. 1. shows, the crystallization curve of salicylic acid occupies nearly the whole concentration interval of the system. The curve is very gentle over nearly its whole extent, and its slope shows a very sharp increase when the benzine content exceeds 70%. The presence of a gentle portion on the crystallization curve gives rise to the theory that a lowly situated metastable equilibrium between two liquid phases exists in this system. However, even with very great supercooling (by 60°) this equilibrium could not be revealed experimentally. As will be shown below, the existence of a region of metastable stratification with an upper critical solution temperature can be demonstrated indirectly.

TABLE 1

Equilibrium in the System Salicylic Acid-Benzine

Amount of benzine (wt. %)	Crystallization temperature
0.00	155.0°
15.03	148.5
30.00	145.0
53.11	139.5
68.14	135.0
81.05	127.0
91.50	113.0
95.00	102.5

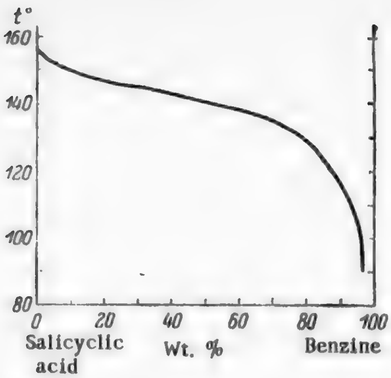

Fig. 1. Equilibrium in the system salicylic acid-benzine.

The Ternary System Salicyclic Acid-Water-Benzine was studied by means of the polythermal sections drawn through its temperature-concentration prism. A total of six such sections was studied, proceeding from the salicylic acid edge to the boundary of the binary system water-benzine, with a benzine content of 5, 20, 40, 60, 80 and 95%. The numerical material obtained for the sections is presented in Table 2. In the nature of an example one of the polytherms is depicted in Fig. 2. In view of the small mutual solubility of the solid and liquid phases close to the boundary of the binary system water-benzine, the solubility in this portion of the ternary system was not studied. For this reason a graphical representation of the monotectic reaction of three phases is not given on the isotherms of the ternary system (Fig. 3) or in its polythermal prism (Fig. 4.).

As Fig. 2 shows, in the polythermal section the crystallization curve (Cr) intersects the equilibrium plane of two liquid phases and in that way divides it into two portions— an upper portion with stable stratification and a lower portion with metastable stratification. Beneath the crystallization curve, in the plane of metastable stratification, a curve with a maximum is present, bounding the equilibrium plane of three liquid phases. The crystallization curve has a gentle, nearly horizontal portion above the plane of the three-phase liquid state. On both sides, in the concentration limits outside of this plane, the curve drops sharply with decrease in temperature. The described form of the salicyclic acid crystallization curve in the polythermal section is similar to the one found in the binary system salicyclic acid-water. In both cases the form of the crystallization curve is conditioned by the presence beneath it of metastable equilibrium between the liquid phases. As a result, here the interesting fact is established that a three-phase metastable liquid equilibrium exerts an influence similar to that of a two-phase equilibrium on the crystallization course.

In the studied ternary system the equilibrium of two liquid phases depends very slightly on the temperature, for which reason in Fig. 2 the curve of the two-phase liquid state is nearly vertical. Thus, a temperature rise of 50° increases the mutual solubility of the two liquid phases a total of only 2%. The curve, bounding the plane of the three-phase liquid state, rises sharply with elevation of the temperature, and shows a gentle maximum in its middle portion (Fig. 2). Thus, in mixtures corresponding to the middle portion of the curve a temperature increase of 1° raises the solubility by 10%; in mixtures containing either less than 10 or more than 35% salicylic acid, a temperature increase of 15° raises the solubility a total of only 3%.

The fact that in all of the polythermal sections the plane of equilibrium of three liquid phases is situated beneath the crystallization curve shows that in the ternary system the whole volume of the three-phase liquid state is found beneath the crystallization surface of salicylic acid. As a result, in the studied ternary system the three-phase liquid equilibrium is metastable at all concentrations and temperatures. In going from section to section, in measure with increasing the percent of benzine in them, the planes of the ternary liquid state gradually shrink. Consequently, the volume of the equilibria of three liquid phases is located in the prism of the ternary system between the benzine edge and the boundary of the binary system salicylic acid-water as Table 2 shows, in all of the polythermal sections the maximum on the curve bounding the plane of the three-phase liquid state, is found at a temperature of about 103.5°. Consequently, in the studied ternary system 103.5° corresponds to the

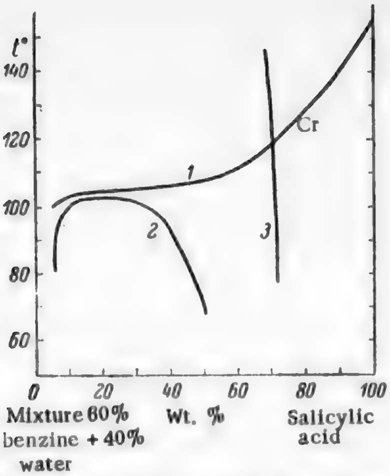

Fig. 2. Polythermal section through the prism of the ternary system water-benzine-salicylic acid. 1) Region of two-phase equilibrium; 2) region of three-phase metastable equilibrium; 3) region of two-phase metastable equilibrium.

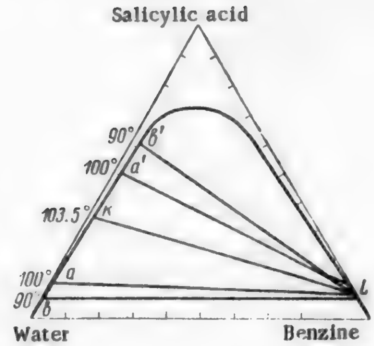

Fig. 3. Isotherms of the ternary system water-benzine-salicylic acid.

temperature of the critical conode of the equilibrium volume of three liquid phases.

From the experimentally obtained polytherms we constructed the isothermal sections of the prism for the ternary system water-benzine-salicylic acid at 90 and 100°. The projection of the lines of the sections on the composition triangle is depicted in Fig. 3, where the projection of the critical conode KL is also plotted. The curve of the two-phase liquid equilibrium at 100° is not shown in Fig. 3, since it nearly coincides with the similar curve at 90°. Due to the fact that in the ternary system salicylic acid-water-benzine the critical conode is found at 103.5°, then above this temperature the stratification of the binary system water-benzine homogenizes into the salicyclic acid ternary system. This is explained by the structure of the salicylic acid molecule, containing both a hydrocarbon radical and functional groups – carboxyl and hydroxyl – the latter both capable of hydration. The maximum amount of salicyclic acid in the heterogeneous mixtures of the ternary system at 90° is 72%. In Fig. 3. the triangle aa'L represents the equilibrium triangle of the three liquid phases at 100°, the compositions of which correspond to the vertexes of the triangle. The triangle bb'L is a similar triangle at 90°. The fields lying adjacent to the sides of these triangles are fields of two-phase liquid equilibrium, in which connection due to the fact that the stratification region lying adjacent to the side aa' (or bb') is extremely narrow, it could not be bounded experimentally and in Fig. 3. coincides with the indicated side. Point K corresponds to the mixture 2% benzine, 64% water and 34% salicylic acid, and L corresponds to 91% benzine, 1% water and 8% acid.

The described polythermal and isothermal sections permit making a plot of the temperature-concentration prism of the ternary system water-benzine-salicylic acid. Due to the extremely small mutual solubility of the phases in some portions of the equilibrium diagram the prism is depicted in simplified qualitative form in Fig. 4, where the components of the ternary system are designated by their initial designation letters. In the figure the plane $9K_1 10$ is the stratification plane of the binary system salicylic acid-water, and the plane $7K_2 8$ is the stratification plane of the binary system benzine-water. The volume KLNOP is the equilibrium volume of the three liquid phases. It is bounded by the two surfaces - KLNP and KLNO, along which the limiting conodes of the two-phase liquid state shift with change in the temperature. Close to the benzine edge these surfaces meet at an angle on the curve LN, and at the top they merge into the critical conode KL. Close to the boundary of the binary system salicylic acid-water the indicated volume is bounded by the plane OKP, along which the limiting equilibrium conodes of two liquid phases shift with change in the temperature. With elevation of the latter these conodes become shorter and at 103.5° they migrate into the initial critical point K of the three-phase liquid equilibrium. Above this temperature the volume of the two-phase liquid state $3bK_2 4$ of the ternary system gradually shrinks and migrates into the upper critical point K_2 of the binary system water-benzine. As was described, the equilibrium of the three liquid phases of the system is completely unstable. In accord with this the volume of the three-phase liquid state KLNOP is situated entirely under the salicylic acid crystallization surface ABC.

A metastable equilibrium of three liquid phases, realized in the ternary system water-benzine-salicylic acid, originates and changes in the following manner. There is one stratification region 1a2 (Fig. 4, Section I) in the ternary system at elevated temperatures. Under these conditions the stratification of the binary system water-benzine homogenizes into the ternary system containing salicylic acid. When the temperature is reduced to 103.5° (Fig. 4, Section II) the initial critical point K of the three-phase liquid equilibrium arises on the binodal curve. The coexisting solution L corresponds to it. As a result, the critical conode KL of the three-phase liquid state appears on the stratification region 3b4. Beginning with this temperature the critical conode develops into the equilibrium diagram of the three liquid phases and the volume of the three-phase liquid state is formed in the prism. Triangle MSF divides the region of the two-phase liquid equilibrium into three portions. This condition is depicted in Fig. 4 in Section III, found at one of the temperatures between 103.5° (temperature of the critical conode) and 89.1° (upper critical solution temperature in the binary system water-salicylic acid). Each of these portions lies adjacent to one of the sides of the three-phase triangle. At the same time its sides are the limiting conodes of the formed two-phase liquid equilibrium regions. The region 5FM6 is situated between the solubility break 5, 6 of the binary system water-benzine and the limiting conode FM. With reduction in the temperature the region STF expands from its limiting conode SF to the boundary of the binary system salicylic acid-water and at 89.1°, i.e., at the temperature of the crit. pt. for the system, it reaches its limits in the critical point K_1. Further reduction of the temperature leads to the formation of region 9OP10, situated between the solubility break 9, 10 of the binary system salicylic acid-water and the limiting conode OP.

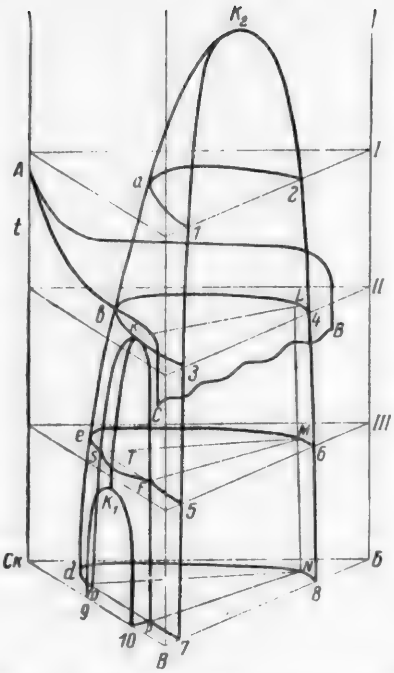

Fig. 4. Simplified qualitative form of the temperature-concentration prism of the ternary system water-benzine-salicylic acid. (The three-phase monotectic reaction is not shown).

As a result, if above 89.1° the predominating system in the ternary system water-benzine-salicylic acid is the binary system salicylic acid-water, then below this temperature the predominating system becomes the binary system salicylic acid-benzine. This is supported by the fact that the binary predominating system of the given ternary system appears as such only in certain temperature limits and does not appear unalterable in the whole temperature range of the ternary system. Consequently, 89.1° is the temperature of change in predominance for the ternary system water-benzine-salicylic acid. It is quite evident that in ternary systems with equilibrium of three liquid phases the temperature of change in predominance will always coincide with the critical solution temperature of the binary component system that occupies an intermediate position between the other two in this respect.

With reduction of the temperature the region SMe stretches from the limiting conode SM toward the boundary of the binary system salicylic acid-benzine, here close to stratification. With further reduction in the temperature the indicated region reaches the boundary of the binary system salicylic acid-benzine, and in this system from this moment a solubility break will appear and expand. Consequently, the binary system salicylic acid-benzine should be considered as being a system with stratification and with a very lowly situated upper critical solution temperature. The latter is found considerably below 89.1°.

The described picture of the origin of metastable equilibrium between three liquid phases is completely analogous to the situation that prevails for a stable three-phase liquid equilibrium. This means that the origin and change in the stable and metastable equilibria of three liquid phases in ternary systems proceed by the same

TABLE 2

Polytherms of the System Salicylic Acid-Water-Benzine

Section No.	Amount of salicylic acid (wt. %)	Temperature of		
		Crystallization	Two-phase stratification	Three-phase stratification
Section *I*	49.00	—	90.0	—
	50.00	—	109.0	—
Section *II*	6.00	—	—	89.0
	7.00	—	—	96.0
	10.00	102.0	—	98.0
	20.00	104.0	—	102.0
	30.00	104.5	—	103.0
	40.00	105.0	—	101.0
	45.00	—	—	99.0
	55.00	—	—	90.0
	60.00	106.0	—	81.0
	69.00	—	120.0	—
	70.00	110.0	105.0	—
	71.00	—	78.0	—
	80.00	119.0	—	—
	90.00	134.0	—	—
	100.00	155.0	—	—
Section *III*	7.00	—	—	92.0
	10.00	103.0	—	100.0
	20.00	104.0	—	103.0
	30.00	105.0	—	104.0
	40.00	106.0	—	100.0
	50.00	107.0	—	90.0
	60.00	108.0	—	—
	70.00	112.0	125.0	—
	72.00	—	102.0	—
	73.00	—	80.0	—
	80.00	121.0	—	—
	90.00	147.0	—	—
	100.00	155.0	—	—
Section *IV*	6.00	—	—	85.0
	9.00	103.0	—	100.0
	18.00	104.0	—	102.5
	23.00	104.5	—	103.0
	33.00	105.0	—	100.0
	37.00	105.0	—	98.0
	41.00	106.0	—	89.0
	50.00	108.0	—	70.0
	60.00	110.0	—	—
	69.00	—	136.0	—
	70.00	118.0	113.0	—
	71.00	—	91.0	—
	80.00	128.0	—	—
	90.00	140.0	—	—
	100.00	155.0	—	—
Section V	6.00	—	—	80.0
	7.30	—	—	100.0
	9.00	107.0	—	103.0
	16.00	108.0	—	104.0
	22.00	—	—	100.0
	23.00	109.0	—	96.0
	28.00	109.5	—	87.0
	40.00	112.0	—	—
	50.00	113.0	-	—
	60.00	115.0	—	—
	69.00	—	141.0	—
	70.00	123.0	124.0	—
	71.00	—	98.0	—
	80.00	134.0	—	—
	90.00	146.0	—	—
	100.00	155.0	—	—
Section *VI*	48.00	—	80.0	—
	49.00	—	102.0	—
	50.00	—	125.0	—

polythermal scheme. In the studied ternary system, together with the stable two-phase equilibrium of the binary system water-benzine, the metastable equilibrium between the two liquid phases of the other two binary systems formed by salicylic acid participated in the formation of the volume of the metastable three-phase liquid state.

SUMMARY

1. The binary system salicylic acid-benzine was studied by the fusion method. The gentle slope of the salicylic acid crystallization curve and other tokens indicate the presence in the system of metastable equilibrium between two liquid phases with an upper critical solution temperature situated considerably below 89.1°.

2. A study was made of the equilibrium of the solid and liquid phases in the ternary system water-benzine-salicylic acid. A volume of metastable equilibrium between the three liquid phases was shown to be present at temperatures below 103.5° (temperature of the critical conode). The compositions of the coexisting solutions of the critical equilibrium conode of the three liquid phases were determined. In the prism of the ternary system the indicated volume is situated between the boundary of the binary system water-salicylic acid and the benzine edge. The shape and temperature-concentration limits of the volume of the three-phase equilibrium were found.

3. It was shown that the polythermal scheme for the origin and change of metastable equilibrium between three liquid phases in ternary systems is the same as for the case of stable equilibrium.

4. An understanding of the temperature of change in predominance was elucidated. In the studied ternary system it is equal to 89.1°.

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FUSION DIAGRAMS OF SYSTEMS CONTAINING HEXACHLOROETHANE. III.

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Earlier one of us [1] had shown that the crystallization branches of the eutectic fusion diagrams of many systems composed of substances of extremely diverse nature are described by Schrader's equation without any concentration limitations, i.e., in other words the laws of ideal solutions are observed in concentrated solutions with incomparably greater frequency than had been assumed up to now.

In the present study we decided to elucidate the possibility of applying the Schrader equation to the case where one of the components exists in the form of several modifications, and to calculate the fusion heats and melting points of the modifications.

In connection with this we made a thermal analysis of some systems with hexachloroethane, capable of existing in three modifications, as the common component, and with anthracene, naphthalene, p-dichlorobenzene, benzene and ethyl trichloroacetate as the second components.

From the literature [2] it is known that hexachloroethane changes from the rhombic form to the triclinic at 45.1 - 46.6°, and from the triclinic to the cubic form at 71.1°.* Steinmetz [3] used the dilatometric method to study hexachloroethane and found that the points for the transition of the α-modification into the β- and of the β- into the γ-modification lie at 71 and 45°, respectively. According to the data of Wiebenga [4], the temperature for the transition of the triclinic form of hexachloroethane lies in the range 70.83 - 71.15°, and for the transition of the cubic form into the rhombic in the range 46.3 - 46.7°.

As the second components we selected those substances which, in our opinion, would give ideal systems with hexachloroethane and would differ as much as possible from each other in their melting points. We selected ethyl trichloroacetate for the reason that it has a high boiling point and a low melting point, which made it possible for us to obtain the hexachloroethane liquidus curve over the expanse of nearly the whole diagram.

EXPERIMENTAL

a) Purification of the Compounds and Method of Operation

The naphthalene was purified by 3-fold distillation and had m.p. 80°. The p-dichlorobenzene was purified by distillation; the fraction boiling at 169.5° and 701 mm Hg pressure was taken; m.p. 53°. The benzene of "cryoscopic" quality was distilled and then purified by fractional freezing; m.p. 5.5°. The ethyl trichloroacetate was synthesized by us and was purified by distillation; the fraction with b.p. 167° (696.5 mm) was taken. The c.p. anthracene and hexachloroethane were not subjected to special purification.

To obtain the fusion diagrams the cooling curves were recorded by the earlier described method [1].

b) Measurement Results

1. System Hexachloroethane-Anthracene. The data obtained in studying the system hexachloroethane-anthracene by the thermal analysis method are given in Table 1 and plotted in Fig. 1.

As can be seen from Fig. 1, the fusion diagram of the system hexachloroethane-anthracene has one eutectic. Along curve AE hexachloroethane crystallizes as the α-modification, while anthracene crystallizes along the curve BE. The eutectic point E corresponds to the composition 74 mole % hexachloroethane and temperature 139°. On the cooling curves, in addition to the breaks corresponding to the start of crystallization and to the

* Subsequently we will designate the cubic form as the α-modification, the triclinic as the β-modification, and the rhombic as the γ-modification.

TABLE 1

Amount of C_2Cl_6 (mole %)	Temperature of			
	Start of crystallization	Transition $\alpha \rightleftarrows \beta$	Transition $\beta \rightleftarrows \gamma$	Crystallization of the eutectic
0.0	213.0°	—	—	—
24.2	194.0	71.0°	42.0°	138.0°
33.9	182.9	70.0	42.0	139.0
49.6	170.0	71.0	42.5	139.0
60.0	160.0	70.0	42.0	138.0
68.2	149.0	70.0	42.0	139.0
73.8	140.0	70.0	41.0	139.0
83.0	154.0	71.0	42.0	139.0
91.8	164.0	70.0	42.0	139.0

TABLE 2

Amount of C_2Cl_6 (mole %)	Temperature of			
	Start of crystallization	Transition $\alpha \rightleftarrows \beta$	Transition $\beta \rightleftarrows \gamma$	Crystallization of the eutectic
0.0	80.0°	—	—	—
10.0	74.1	—	39.2°	55.8°
17.7	71.0	—	38.0	55.9
26.7	63.3	—	39.0	56.2
33.0	59.0	—	39.2	56.2
35.1	57.7	—	39.0	56.2
38.1	60.0	—	38.6	56.1
42.0	64.0	—	39.0	56.2
45.1	68.5	—	38.8	56.1
48.7	73.0	70.0°	39.9	56.1
50.1	78.0	70.0	37.0	56.0
52.0	83.0	70.0	39.3	56.1
54.2	85.0	70.0	40.0	56.1
55.1	94.0	70.0	40.0	56.3
60.6	107.0	70.0	38.0	56.4
70.2	130.0	70.0	37.5	55.6
85.3	157.0	70.0	41.0	56.0

temperature rest during crystallization of the eutectic, we observed two temperature rests: at 71°, corresponding to transition of the α-modification into the β-form, and at 42°, corresponding to transition of the β-modification into the γ-form.

2. System Hexachloroethane-Naphthalene. For the system hexachloroethane-naphthalene we recorded the cooling curves for 16 mixtures. All of the mixtures in the molten state represent colorless, transparent liquids, crystallizing almost without supercooling.

The data on the fusibility are given in Table 2 and plotted in Fig. 2. The fusion diagram of this system has the form characteristic for systems with polymorphous tranformation. In the diagram hexachloroethane crystallizes as the α-modification along curve AC_1, along curve C_1E_1 it crystallizes as the β-modification, while naphthalene crystallizes along the curve B_1E_1. Transformation of the α- into the β-modification occurs at point C_1 at a temperature of 70°. The eutectic point E corresponds to the composition 65 mole % hexachloroethane and temperature 56.2°.

Rests are observed on all of the cooling curves, corresponding to transformation of the β- into the γ-modification. They lie in the range 38 - 41°, i.e., somewhat below the transition points obtained by us in studying the other systems.

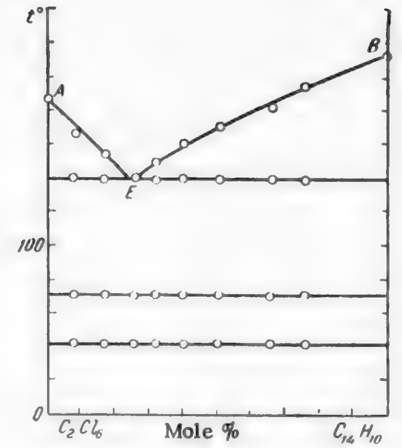

Fig. 1. Fusion diagram of the system C_2Cl_6—$C_{14}H_{10}$.

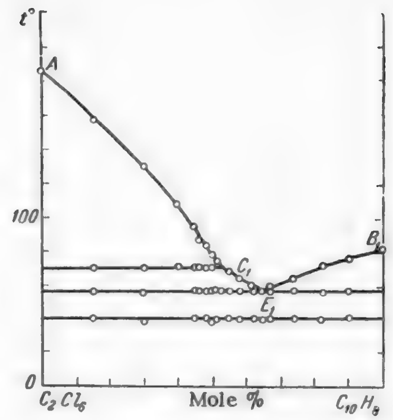

Fig. 2. Fusion diagram of the system C_2Cl_6—$C_{10}H_8$.

3. System Hexachloroethane-p-Dichlorobenzene. In studying the system hexachloroethane-p-dichlorobenzene by the thermal analysis method we recorded the cooling curves for 20 mixtures.

All of the mixtures in the molten state represent colorless liquids. The thermal analysis data for the system hexachloroethane-p-dichlorobenzene are given in Table 3, while the fusion diagram is depicted in Fig. 3.

From Fig. 3 it can be seen that the hexachloroethane liquidus curve has two breaks: in point C_1 at 71° there occurs transition of the α-modification into the β-form, and in point C_2 at 42° there occurs transformation of the β-modification into the γ-form. Along curve C_1C_2 hexachloroethane crystallizes as the β-modification, and along curve C_2E_2 as the γ-modification. The eutectic point corresponds to temperature 38° and composition 25.3 mole % hexachloroethane. Exceedingly distinct eutectic rests were obtained on the cooling curves. For the mixtures close in composition to the eutectic the temperature rest lasted for up to 2 hours. We were unable to obtain the breaks corresponding to the start of crystallization for the mixtures, for which reason the temperature corresponding to the appearance of the first crystals was determined visually.

4. System Hexachloroethane-Benzene. For the system hexachloroethane-benzene we recorded the cooling curves for 25 mixtures. The data on the fusibility of this system are given in Table 4 and plotted in Fig. 4. The α-modification of hexachloroethane crystallizes along the curve AC_1; transition of the α-modification into the β-form occurs in point C_1 at 70°. Hexachloroethane crystallizes as the β-modification along curve C_1C_2; transformation of the β-modification into the γ-form occurs at 42° (in point C_2). The γ-modification crystallizes along curve C_2E_3.

The branch AC_1, corresponding to crystallization of the α-modification of hexachloroethane, breaks off in the point belonging to the mixture containing 53.8 mole % hexachloroethane; we were unable to record the cooling curves for the mixtures with a higher content of hexachloroethane, since above 90° the mixtures began to boil. The eutectic mixture crystallized at −0.9° and contained 10.0 mole % hexachloroethane.

5. System Hexachloroethane-Ethyl Trichloroacetate. The data on the thermal analysis of the system hexachloroethane-ethyl trichloroacetate are presented in Table 5 and plotted in Fig. 5. As can be seen from the plot, the hexachloroethane liquidus curve extends through the whole diagram.

Hexachloroethane crystallizes as the α-modification along the curve AC_1; transition of the α-modification into the β-form is accomplished in point C_1 at 70°. Along curve C_1C_2 hexachloroethane crystallizes as the β-modification. Transition of the β-modification into the γ-form is realized at 42° in point C_2. The γ-modification crystallizes along curve C_2C_3. Due to the low melting point of ethyl trichloroacetate, both the ethyl

trichloroacetate liquidus curve and the eutectic are absent on the fusion diagram.

TABLE 3

Amount of C_2Cl_6(mole%)	Temperature of			
	Start of crystallization	Transition $\alpha \rightleftarrows \beta$	Transition $\beta \rightleftarrows \gamma$	Crystallization of the eutectic
0.0	53.0°	—	—	—
11.1	47.6	—	—	38.0°
16.7	44.0	—	—	38.0
20.0	42.0	—	—	37.9
23.0	40.0	—	—	38.0
25.3	38.0	—	—	38.0
26.6	41.0	—	—	38.0
26.9	42.0	—	—	38.0
29.0	46.0	—	42.0°	38.0
30.0	47.0	—	40.0	38.0
32.2	50.0	—	42.0	38.0
33.4	53.4	—	41.6	38.0
36.7	58.0	—	42.0	38.0
40.5	62.0	—	42.0	38.0
43.4	65.8	—	42.0	38.0
45.2	68.0	—	42.0	38.0
49.9	76.0	70.0°	43.0	38.0
50.0	77.4	70.0	43.0	38.0
60.1	107.0	71.0	43.2	37.8
70.0	130.0	71.0	41.6	37.4
79.2	149.0	70.0	41.8	37.4

TABLE 4

Amount of C_2Cl_6(mole %)	Temperature of			
	Start of crystallization	Transition $\alpha \rightleftarrows \beta$	Transition $\beta \rightleftarrows \gamma$	Crystallization of the eutectic
0.0	5.5°	—	—	—
2.9	4.5	—	—	—0.9°
4.8	3.0	—	—	—0.9
6.8	1.4	—	—	—0.9
10.0	—	—	—	—0.9
10.9	4.0	—	—	—0.9
12.1	7.0	—	—	—0.9
15.9	16.5	—	—	—0.9
17.0	19.0	—	—	—0.9
20.5	26.0	—	—	—0.9
23.0	32.0	—	—	—0.9
24.5	36.0	—	—	—0.9
24.8	37.5	—	—	—0.9
26.9	41.0	—	—	—0.9
28.0	43.0	—	—	—0.9
29.0	45.0	—	41.7°	—0.9
29.4	46.0	—	42.0	—0.9
29.8	47.0	—	41.8	—0.9
34.0	53.5	—	41.7	—0.9
36.0	57.0	—	41.8	—0.9
42.5	64.0	—	42.0	—0.9
44.8	67.6	—	42.0	—0.9
46.6	71.0	70.0°	42.0	—0.9
47.8	73.4	70.0	41.8	—0.9
49.8	78.0	70.0	42.2	—0.9
53.8	90.0	70.0	42.5	—0.9

TABLE 5

Amount of C_2Cl_6 (mole %)	Temperature of		
	Start of crystallization	Transition $\alpha \rightleftarrows \beta$	Transition $\beta \rightleftarrows \gamma$
3.4	−18.0°	—	—
14.9	+15.3	—	—
19.5	26.0	—	—
23.6	35.2	—	—
24.1	36.5	—	—
25.1	38.0	—	—
26.0	40.0	—	—
27.1	42.0	—	41.5°
27.5	43.0	—	41.5
28.3	44.5	—	42.0
31.6	50.5	—	42.0
33.4	53.0	—	42.0
38.2	60.5	—	41.8
43.7	67.5	—	41.6
45.9	71.0	70.0°	41.8
47.8	74.8	70.0	41.8
56.1	98.0	70.0	42.5
67.2	124.0	70.3	42.8
75.6	140.5	70.2	41.5
90.6	163.0	70.0	42.0

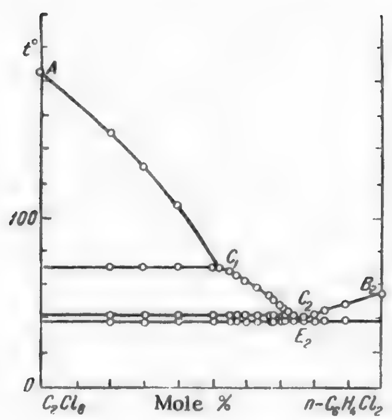

Fig. 3. Fusion diagram of the system C_2-Cl_6—π -$C_6H_4Cl_2$.

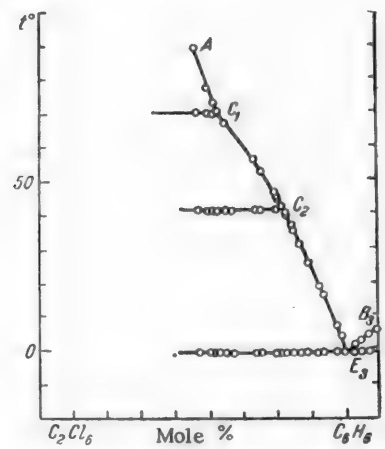

Fig. 4. Fusion diagram of the system C_2-Cl_6—C_6H_6.

DISCUSSION OF RESULTS

To compare the results we plotted all of the data obtained by us on one diagram (Fig. 6). From the plot it can be seen that the points corresponding to the temperature of the start of hexachloroethane crystallization (for all five systems) fall quite well on one hexachloroethane liquidus curve, consisting of three branches, and also that the hexachloroethane liquidus curve passes through nearly the whole fusion diagram (up to 3.4 mole % of hexachloroethane). The extent of the hexachloroethane liquidus curve becomes smaller the higher the melting point of the second component. Anthracene has a high melting point (213°), and consequently the hexachloroethane liquidus curve in the system hexachloroethane-anthracene has a short extent: it embraces the small crystallization region of the hexchloroethane α-modification. In this system the transition of the α-modification

into the β-form and of the β- into the γ- is accomplished in the absence of a liquid phase (below the eutectic temperature).

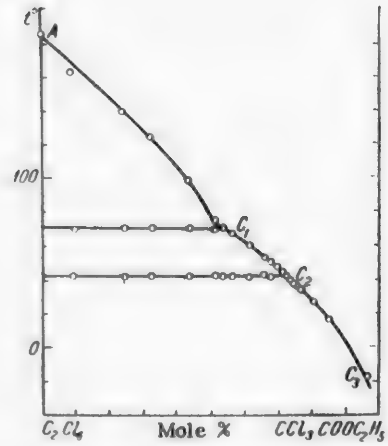

Fig. 5. Fusion diagram of the system C_2Cl_6–$CCl_3COOC_2H_5$.

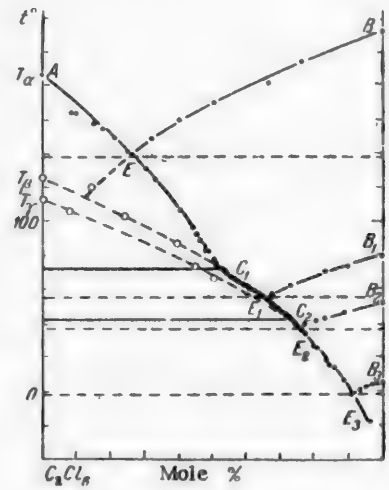

Fig. 6. Comparison of the fusion diagrams of the systems.

Not only the crystallization branch of the α-modification is realized in the system hexachloroethane-naphthalene, but also a considerable portion of the crystallization branch of the β-modification; transformation of the β-modification into the γ-form also occurs in the absence of a liquid phase. Crystallization branches of the α- and β-modifications and a partial crystallization branch of the γ-modification were obtained in the system hexachloroethane-p-dichlorobenzene. The crystallization branch of the γ-modification shows considerable extent in the systems hexachloroethane-benzene and hexachloroethane-ethyl trichloroacetate.

To answer the question of whether Schrader's equation is obeyed in the given case, we constructed the logarithmic plots of Schrader separately for each of the branches of the hexachloroethane liquidus curve. The diagram showing the relationship between log x and $\frac{1}{T}$ for the crystallization branches of the α-, β- and γ-modifications is given in Fig. 7.

The straight line I expresses the relationship between log x and $\frac{1}{T}$ for the α-modification, the straight line II for the β-modification, and the straight line III for the γ-modification. From the figure it can be seen that the points relating to the different systems fall quite well on the straight lines. Extrapolating the straight lines I, II and III to their intersection with the ordinate axis (x=0), we found the melting points of the α-, β- and γ-modifications. The melting point of the hexachloroethane α-modification proved to be equal to 187°. P. Lee [5] found that the melting point of the hexachloroethane α-modification is equal to 187°, and according to the data of Wiebenga [4] it is equal to 186.8°. For the β- and γ-modifications we obtained melting points respectively equal to 126.8 and 114.8°. Pascal [4] mentions transition points of 125 and 71.6°. We believe that the transition point of 125° found by Pascal corresponds to the melting point of the β-modification. Pascal probably obtained a lower melting point (125°) than we did by extrapolation (126.8°) for the reason that he added 1.5-2% of naphthalene to the hexachlorethane. From a comparison of these data it can be seen that the melting point found by us for the β-modification is highly plausible. On the fusion diagram (Fig. 6) the melting points calculated by us are designated by the points T_α, T_β, and T_γ. At these points we extrapolated the crystallization branches of the α-, β- and γ-modifications, depicted in the figure by dotted lines. In this region of metastable equilibria we were able to realize 6 points. To realize the metastable equilibria we proceeded as follows: the mixture, prepared in large amount, was melted with vigorous stirring and then was kept at room temperature for a day; the next day the mixture was crushed in a mortar, heated as rapidly as possible to the melting point, and then the cooling curve was recorded. Thus we were able to realize in a practical manner the crystallization branches of the β- and γ-modifications, and also to continue the crystallization branch of anthracene into the

region of metastable equilibrium.

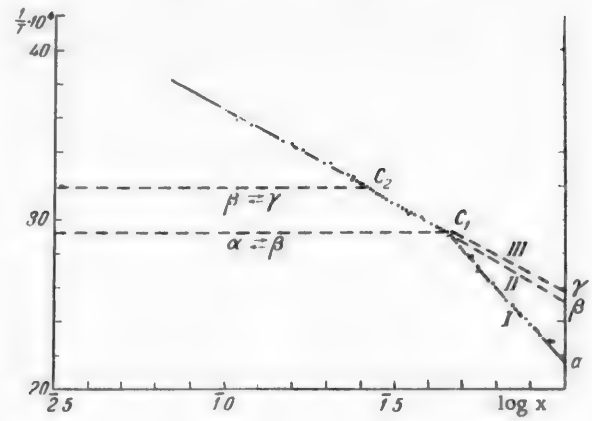

Fig. 7. Logarithmic plot of Schrader.

On the crystallization branch of the β-modification we obtained points corresponding to the compositions 60 and 75 mole % hexachloroethane (with naphthalene) and temperatures 88 and 104°, respectively. A temperature rest corresponding to transition of the α-modification into the β-form was absent on the cooling curves of these mixtures. On the crystallization branch of the γ-modification we obtained points, corresponding to the compositions 49 mole % hexachloroethane (with p-dichlorobenzene), 92 mole % hexachloroethane (with anthracene) and 55 mole % hexachloroethane (with naphthalene) and the temperatures 67, 107 and 72.5°, respectively. On the crystallization branch of anthracene in the region of metastable equilibrium we were able to realize a point corresponding to the composition of a mixture containing 85 mole % of hexachloroethane and a temperature of 120°.

From Schrader's equation and the hexachloroethane liquidus curve we calculated the fusion heats of the modifications. In Table 6 we present the results of calculating the values of $K=\frac{RT_0}{Q}$ in Schrader's equation, and also the fusion heats. As can be seen from Table 6, the value of K for the α-modification fluctuates slightly around the average value of 0.435. The fusion heat of the α-modification, calculated from K, is 2.10 kcal /mole. On the basis of the vapor tension data for hexachloroethane P. Lee [5] calculated the fusion heat of the α-modification and found it to be equal to 2.4 kcal /mole. We see that our data are in good agreement with Lee's data.

TABLE 6

Modification of C_2Cl_6	Mole % of C_2Cl_6	T_0	T	ΔT	K	$K_{a.v.}$	Heat of fusion (kcal./mole)
α	85.3	460.2	430.2	30.0	0.439	0.435	2.095
	70.2	460.2	403.2	57.0	0.400		
	60.6	460.2	380.2	80.0	0.473		
	55.1	460.2	367.2	93.0	0.425		
	52.4	460.2	358.2	102.0	0.441		
β	38.2	400.0	333.7	66.3	0.207	0.206	3.845
	53.0	400.0	325.2	73.8	0.206		
	43.0	400.0	316.2	83.7	0.205		
γ	26.9	388.0	314.2	73.8	0.179	0.182	4.221
	24.8	388.0	310.7	77.3	0.178		
	23.1	388.0	305.2	82.8	0.186		
	20.5	388.0	299.2	88.8	0.184		
	15.9	388.0	289.7	98.3	0.184		

For the β-modification the heat of fusion proved to be equal to 3.8 kcal /mole, and for the γ-modification it was equal to 4.2 kcal /mole. The values of K for the β- and γ-modifications remain practically constant over the whole concentration range, and their average values are respectively equal to 0.206 and 0.182.

From the fusion heats of the modifications we calculated the transition heats and obtained for the transition of the α-modification into the β-form a value of 1.75 kcal /mole, and for the transition of the β-modification into the γ-form a value of 0.38 kcal /mole.

As a result, from the presented data it can be seen that Schrader's equation makes it possible to calculate both the fusion heats and the melting points of the modifications.

SUMMARY

1. The thermal analysis method was used to study the systems hexachloroethane-anthracene, hexachloroethane-naphthalene, hexachloroethane-p-dichlorobenzene, hexachloroethane-benzene and hexachloroethane-ethyl trichloroacetate.

2. It was shown that the hexachloroethane liquidus curve, consisting of three branches, coincides in all of the five systems studied by us and that all of its branches are described by Schrader's equation.

3. On the basis of the obtained data we calculated with the aid of Schrader's equation both the fusion heats and the melting points of the α-, β- and γ-modifications.

4. The heats for the transition of the α-modification into the β-form and of the β-form into the γ-modification were calculated.

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PHYSICOCHEMICAL ANALYSIS OF THE TERNARY SYSTEM UREA-ACETIC ACID-MONOCHLOROACETIC ACID

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In this paper we give the results of studying the diagram of state of the ternary system urea-acetic acid-monochloroacetic acid. As had been shown in studying the binary systems, urea with acetic acid and its chloroderivatives forms compounds the stability of which increases with increase in the number of chlorine atoms in the acetic acid radical [1-3]. It seemed of interest to follow the character of the chemical reaction of urea with acetic acid in its mutual presence with monochloroacetic acid. Together with this, such a study is of practical importance, since it is known that urea is used in the manufacture of carbamide resins together with organic acids, the latter functioning as condensing agents. Urea, being a good mineral fertilizer, can also be found in the soil together with monochloroacetic acid, the latter functioning as a herbicide for killing weeds [4].

The visual-polythermal method was used in making the study. The temperatures at which the first crystals appeared on cooling and the last crystals disappeared on heating were determined for each solution until the difference in the indicated temperatures did not exceed one degree. In the case of supercooling of the system, the temperature at which the last crystals disappeared was taken as the base.

The starting substances needed for the study were purified by either repeated crystallization or distillation and had constants close to those given in the literature [5].

Binary Systems

1. The System Urea-Acetic Acid was studied by a number of authors [6-8]. The presence of the compound $CO(NH_2)_2 \cdot 2CH_3COOH$ was established in the system, which appears as a maximum on the composition-property diagram. This compound is already substantially dissociated at its melting temperatures.

2. The System Urea-Monochloroacetic Acid contains a considerable amount of the dissociated compound $CO(NH_2)_2 \cdot 2CH_2ClCOOH$ [9]. Based on later data, the presence of two strongly dissociated compounds — $CO(NH_2)_2 \cdot 2CH_2ClCOOH$ and $CO(NH_2)_2 \cdot CH_2ClCOOH$ [1] was established in the system [1].

3. The System Acetic Acid-Monochloroacetic Acid is characterized by a simple eutectic and does not form compounds [10].

Ternary System

To develop the crystallization surface of the ternary system we studied seven sections in the directions indicated in Fig. 3. The numbers of the sections correspond to the numbers of the curves in Figs. 1 and 2.

Section I (85.11 mole % monochloroacetic acid and 14.89 mole % urea) intersects the acetic and monochloroacetic acid fields (Table 1). The point of intersection of the branches (Fig. 1) corresponds to 69 mole % acetic acid at $-9°$.

Section II (86.3% acetic acid and 13.7 mole % monochloroacetic acid) intersects the fields of acetic acid, compound $CO(NH_2)_2 \cdot 2CH_3COOH$ and urea. The points of intersection of the branches correspond to: a_1 — 6.0 mole % urea at 5°, and a_2 — 42.3 mole % urea at 32° (Fig. 1).

Section III (65.58 mole % monochloroacetic acid and 34.42 mole % acetic acid) intersects the fields of monochloroacetic acid, compound $CO(NH_2)_2 \cdot 2CH_2ClCOOH$, compound $CO(NH_2)_2 \cdot CH_2ClCOOH$ and urea (Table 2). The points of intersection of the branches correspond to: a_1 — 17 mole % urea at 19°, a_2 — 35 mole % urea at 21°, and a_3 — 47 mole % urea at 28° (Fig. 2).

Section IV (38.84 mole % monochloroacetic acid and 61.16 mole % acetic acid) intersects the fields of monochloroacetic acid, compound $CO(NH_2)_2 \cdot 2CH_3COOH$ and monochloroacetic acid. The points of intersection of the branches correspond to: a_1 — 12 mole % urea at -4°, and a_2 — 41 mole % urea at 16° (Fig. 1).

TABLE 1

Melting Points of Ternary Mixtures (Sections I, II, IV and VII).

Section I		Section II		Section IV		Section VII	
Amount of CH_3COOH (mole %)	Melting point	Amount of $CO(NH_2)_2$ (mole %)	Melting point	Amount of $CO(NH_2)_2$ (mole %)	Melting point	Amount of $CO(NH_2)_2$ (mole %)	Melting point
0.00	50	0.00	7.5	0.00	+11.5	0.00	19.0
7.16	46	2.18	7.0	6.04	+ 4.0	6.31	16.0
24.04	35.1	7.18	4.4	11.96	— 3.5	12.45	6.5
29.44	31.2	13.78	17.8	17.75	+ 2.5	18.43	10.0
43.26	19.1	16.28	21.5	23.42	7.2	24.25	12.6
46.66	16.0	20.69	27.3	25.65	9.0	26.53	12.8
54.92	6.8	24.67	31.2	28.96	13.5	29.91	12.0
69.65	—5.0	28.29	32.16	32.23	15.6	34.24	12.0
73.00	—2.0	32.79	33.8	34.40	16.2	35.43	13.6
76.57	+0.5	37.80	31.0	39.72	16.0	37.60	14.6
79.68	3.0	42.13	35.0	42.86	20.0	40.81	16.5
81.49	4.0	46.29	51.0	44.12	31.0	43.97	19.5
—	—	—	—	50.02	51.0	48.12	40.0

TABLE 2

Melting Points of Ternary Mixtures (Sections III, V and VI).

Section III		Section V		Section VI	
Amount of $CO(NH_2)_2$ (mole %)	Melting point	Amount of $CH_2ClCOOH$ (mole %)	Melting point	Amount of CH_3COOH (mole %)	Melting point
0.00	40.0	0.00	40.0	0.00	42.0
6.76	33.4	3.20	37.6	19.67	27.0
10.69	28.6	6.59	34.9	27.72	19.0
13.26	25.0	10.07	31.5	37.36	12.2
16.00	20.5	13.70	27.6	49.53	17.9
19.55	20.0	17.46	23.0	60.64	19.0
23.21	22.0	21.60	18.0	68.48	18.0
25.61	22.8	25.67	13.0	74.05	15.7
27.94	23.2	30.72	6.5	77.91	14.3
31.45	22.8	34.33	6.5	84.78	6.7
34.87	21.2	38.46	9.8	87.31	8.5
37.12	23.1	43.80	11.5	—	—
39.32	24.5	48.87	13.0	—	—
42.58	26.3	54.19	21.5	—	—
45.77	27.5	—	—	—	—
47.86	33.5	—	—	—	—
49.93	42.5	—	—	—	—
52.98	55.0	—	—	—	—

Section V (70.0 mole % acetic acid and 30.0 mole % urea) intersects the fields of compound $CO(NH_2)_2 \cdot 2CH_3COOH$, compound $CO(NH_2)_2 \cdot 2CH_2ClCOOH$ and monochloroacetic acid. The points of intersection of the branches correspond to: a_1 — 32.0 mole % monochloroacetic acid at 5°, and a_2 — 49 mole % monochloroacetic acid at 14° (Fig. 2).

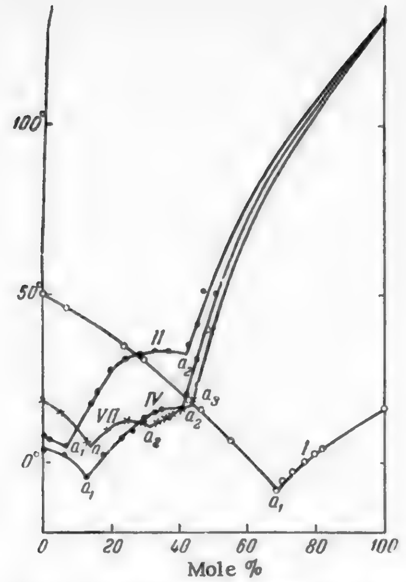

Fig. 1. Fusion curves of ternary mixtures. Sections I, II, IV and VII.

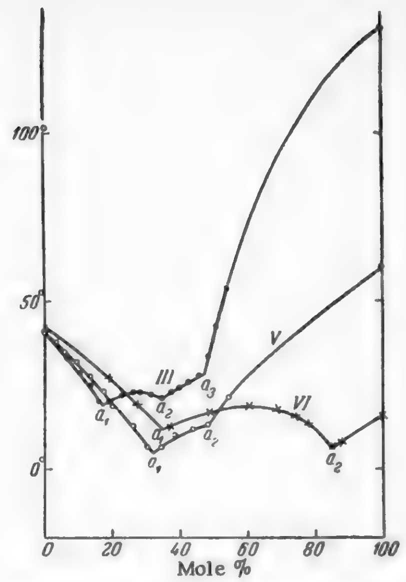

Fig. 2. Fusion curves of ternary mixtures. Sections III, V and VI.

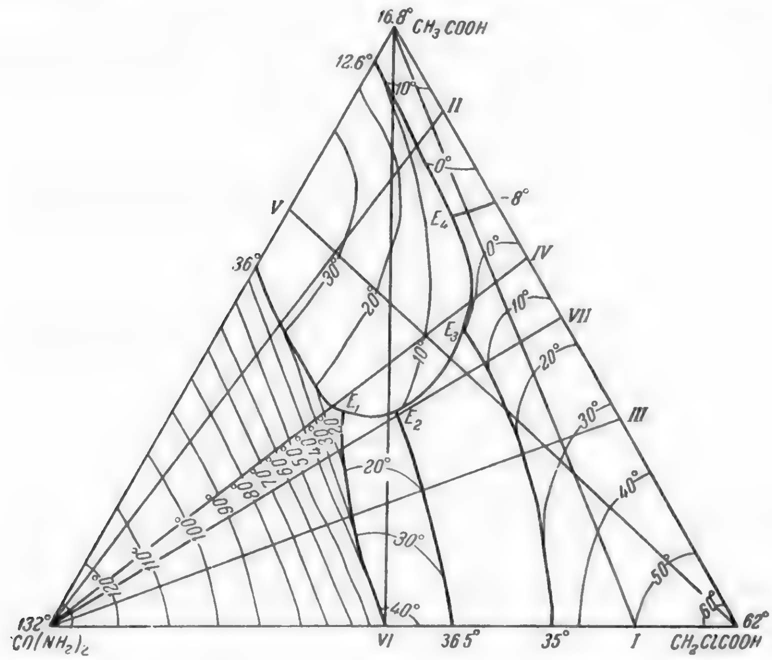

Fig. 3. Fusion diagram of the system $CO(NH_2)_2$ — CH_3COOH — $CH_2ClCOOH$.

Section VI (48.78 mole % monochloroacetic acid and 51.22 mole % urea) intersects the fields of compound $CO(NH_2)_2 \cdot CH_2ClCOOH$, compound $CO(NH_2)_2 \cdot 2CH_3COOH$ and acetic acid. The points of intersection correspond to: a_1 – 35 mole % acetic acid at 12°, and a_2 – 85 mole % acetic acid at 6° (Fig. 2).

Section VII (48.78 mole % monochloroacetic acid and 51.22 mole % acetic acid) intersects the fields of monochloroacetic acid, compound $CO(NH_2)_2 \cdot 2CH_2ClCOOH$, compound $CO(NH_2)_2 \cdot CH_2ClCOOH$ and urea. The points of intersection of the branches correspond to: a_1 – 14.5 mole % urea at 6°, a_2 – 32 mole % urea at 12°, and a_3 – 43 mole % urea at 18° (Fig. 1).

In studying the sections I, IV, V, VI and VII quite strong supercooling was observed in the region of the eutectic points, and the liquid became viscous and occluded air, which made the determinations difficult.

On the basis of our data we constructed the planar fusion diagram of the ternary system urea-acetic acid-monochloroacetic acid and plotted the isotherms at 10° intervals (Fig. 3).

The obtained fusion diagram embraces six crystallization fields: three fields of pure components and three fields that belong to the compounds $CO(NH_2)_2 \cdot 2CH_3COOH$, $CO(NH_2)_2 \cdot 2CH_2ClCOOH$ and $CO(NH_2)_2 \cdot CH_2ClCOOH$.

There are four ternary eutectic points in the system: E_1 – 40 mole % urea, 35 mole % acetic acid and 25 mole % monochloroacetic acid at 15°; E_2 – 35 mole % acetic acid, 32 mole % urea and 33 mole % monochloroacetic acid at 11.5°; E_3 – 14 mole % urea, 52 mole % acetic acid and 34 mole % monochloroacetic acid at –1°; and E_4 – 7 mole % urea, 63 mole % acetic acid and 30 mole % monochloroacetic acid at –10°.

SUMMARY

1. The thermal analysis method was used to study the system urea-acetic acid-monochloroacetic acid. The planar fusion diagram of this system was constructed.

2. The existence of six crystallization fields in the system was established: three regions of pure components and three crystallization fields of the binary compounds $CO(NH_2)_2 \cdot 2CH_3COOH$, $CO(NH_2)_2 \cdot 2CH_2ClOOH$ and $CO(NH_2)_2 \cdot CH_2ClCOOH$. The formation of a chemical compound in the ternary coupling of the components was not observed.

3. The system supplements the earlier made conclusion that the reaction between urea and acetic acid and its chloro derivatives is enhanced in measure with increase in the number of chlorine atoms in the acetic acid radical. The compounds formed in the binary systems are more distinctly revealed in the case of the ternary system.

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THE USE OF REFRACTOMETRY FOR STUDYING COMPLEX FORMATION IN SOLUTIONS OF ELECTROLYTES

I. SYSTEM $CdCl_2$-KCl-H_2O

B. V. Ioffe

As the result of studying numerous literature data and based on our own studies of binary liquid systems we expressed the opinion [1-3] that refractometry permits establishing only the sharply defined chemical reaction of components and should be regarded as belonging with the comparatively low-sensitive methods of studying the chemical compounds formed in solutions. However, there also exists an opposite viewpoint, developed in recent years chiefly by N. F. Ermolenko and co-workers [4-6], which recommends refractometry as being one of the most accurate and convenient methods of establishing the amount and composition of molecular compounds in solutions. Considering the refractometric method as being one of great importance in studying the reactions of salts in solutions, N. F. Ermolenko and co-workers in the course of a number of years used this method to study a large number of salt systems [5, 6, 14]. As we had already mentioned [3, 7], the erroneous formulation of the additivity rule in the mentioned studies and the meaningless nature of the effects, ascribed without proof to the formation of the compounds, causes the conclusions of these studies to be regarded with great skepticism and makes it desirable to review and check them carefully. For such verification we selected the system $CdCl_2-KCl-H_2O$, where the formation of complex compounds has been firmly established by extremely different methods.*

In addition to $Cd^{\cdot\cdot}$ and Cl' ions, it was shown that undissociated $CdCl_2$ molecules, $CdCl^{\cdot}$ cations and $CdCl'_3$ and $CdCl''_4$ anions are present in aqueous cadmium chloride solutions. In the presence of substantial amounts of Cl' ions, i.e., in mixtures containing alkali metal chlorides, the main cadmium mass is present in the form of the complex ions $CdCl'_3$ and $CdCl''_4$. The evaporation of an equimolar mixture of cadmium chloride and potassium chloride solutions yields the compound $KCdCl_3$ as the crystallohydrate with one molecule of water, and from the mixed solutions with a large excess of KCl the hexachloride K_4CdCl_6 crystallizes. These two compounds show up distinctly on the fusion diagram of the binary system $CdCl_2-KCl$.

The system $CdCl_2-KCl-H_2O$ has been studied three times [12-14] by the refractometric method. In the first study [12] the criterion of forming complex compounds was the shape of the index of refraction n_D^{20} curves of three sections of the ternary system. Spacu and Popper [12] asserted that with a high total concentration of salts there are three maxima on the curves for the deviations of the refractive indices of the mixtures from the theoretically calculated values, corresponding as it were to the three complex compounds K_3CdCl_5, K_2CdCl_4 and $KCdCl_3$, formed in solution. In this connection the "theoretical" values of the refractive indices of the ternary mixtures were calculated not by the usual additivity rule, but by a more complicated method, taking into consideration the dependence of the refractive indices of binary systems on the concentration and employing graphical interpolation. Leaving to one side for the time being the question of the validity and fitness of the calculation method used by Spacu and Popper, we will examine in detail their experimental data. A comparison of the refractive indices presented by Spacu and Popper for water (n_D^{20} 1.33277, n_C^{20} 1.33095 and n_d^{20} 1.33251) with the true values [3] leads to the conclusion that the accuracy of the refractive index measurements in the study under discussion does not **exceed several 10^{-4}** units.

* See the recent studies [8, 9], and also [10, 11] and the literature references cited there.

The same conclusion is also reached when a comparison is made of the n_D^{20} values of several aqueous KCl solutions from the first [12] and second [13] papers of Spacu and Popper with some reliable literature data [15] (See Table 1).

It can also be seen from the data in Table 1 that the data on the density agree with each other only to the third place (10^{-3}). A comparison of the data of Spacu and Popper for $CdCl_2$ solutions (Table 2) shows that a gross systematic error (apparently in establishing the $CdCl_2$ concentration) exists in the examined study [12], leading to completely inadmissible divergences in the densities and refractive indices. If we return to the curve for the deviations of n_D^{20} from the "theoretical" values [12], we see that the assertion of three maxima existing on it is based on the presence of two points, forming "minima" and deviating from the smooth curve by a total of only $2\text{-}3 \cdot 10^{-4}$. Taking into consideration what has been said above on the score of the accuracy of the measurements in the examined study and also the fact that a graphical calculation introduces unavoidable supplementary errors, the assertion of Spacu and Popper relative to three maxima reflecting the presence of three complexes of KCl and $CdCl_2$ must be acknowledged to be completely without basis.

TABLE 1

Refractive Indices and Densities of Aqueous Potassium Chloride Solutions

Amount of KCl		Refractive indices n_D^{20}		Difference I-II · 10^5	Density d_4^{20}
Wt. %	g/100 ml	According to Spacu and Popper (I)	According to Wagner [15] (II)		
14.63	16.00	1.35281 [12]	1.35287	— 6	1.0935 [12]
14.75	(16.16)	1.35328 [12]	1.35308	+20	—
14.849	16.29	1.35290* [13]	1.35322	—32	1.09585 [13]
14.889	16.32	1.35298* [13]	1.35326	—28	1.09720 [13]
14.89	16.32	1.35318 [12]	1.35326	— 8	1.0960 [12]
14.91	16.33	1.35328 [12]	1.35327	+ 1	1.0953 [12]

TABLE 2

Refractive Indices and Densities of Aqueous Cadmium Chloride Solutions (According to Spacu and Popper)

Amount of $CdCl_2$ (wt. %)	n_D^{20}	d_4^{20}	Source of data
18.23	1.36653	—	[12]
18.33	1.36622	1.1975	[12]
18.333	1.36311*	1.17984	[13]
18.37	1.36671	1.1977	[12]
24.93	1.38170	—	[12]
27.486	1.38176*	1.29341	[13]
36.664	1.40379*	1.42874	[13]
36.70	1.41292	1.4822	[12]
37.750	1.40404*	1.43030	[13]

In the second paper [13], Spacu and Popper studied the system $CdCl_2 - KCl - H_2O$ more carefully, not saying anything however about the substantial differences between the new data and the former data for the $CdCl_2$ solutions. In this case the criterion of complex formation were the deviations of the specific refraction of the dissolved salt from the "theoretical" value, calculated by the same method as was used in the first paper [12] to calculate the refractive indices. The upper portion of Fig. 1 reproduces exactly the curve for the deviations of the specific refraction Δr, drawn by Spacu and Popper from experimental points. The curve drawn in this manner has three maxima, formed as the result of the falling out of two points ("minima"), standing out from the smooth curve by not more than $1 \cdot 10^{-4}$. According to the assertion of Spacu and Popper, the positions of the "maxima" correspond to the mole ratios $CdCl_2$: KCl =1:1, 1:2 and 1:3, i.e., they correspond to the compounds $KCdCl_3$, K_2CdCl_4 and K_3CdCl_5. However it was recently shown [14] that in determining the ratio of the components Spacu and Popper assumed a substantial error, so that the "maxima" on their Δr curve do not correspond to the indicated ratios of the components and in general only with considerable stretching can be related to any whole number ratios. A

calculation of the possible experimental errors reveals that not only the proposed composition of the complex compounds is without basis, but also the assertion itself that three maxima of Δr are present. The comparative accuracy of the measurements with the ordinary Pulfrich refractometer used in the indicated study does not exceed $0.5 \cdot 10^{-4}$. * An error of $\Delta n = \pm 0.5 \cdot 10^{-4}$ leads to an error of $\Delta r = 1 \cdot 10^{-4}$. The actual accuracy of the specific refraction values for dissolved salts should be considerably lower due to other scurces of error. The Δr curve, drawn with the possible (minimum) experimental errors taken into consideration (Fig. 1, bottom), shows that there is no basis to the assertion that three maxima of Δr are present. The curve for the deviations of the refractive indices from additivity as a function of the volume percents of the mixed solutions, constructed by us from the experimental data of Spacu and Popper [13] (Fig. 2), also fails to give any indications of the presence of three complex compounds.

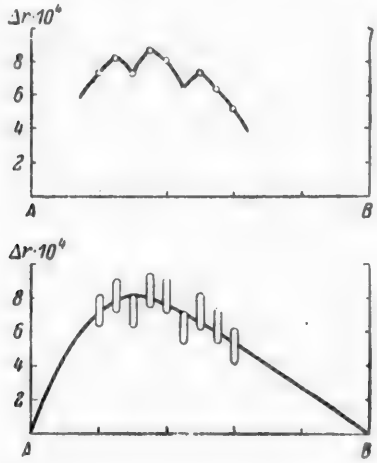

Fig. 1. Deviations of the specific refraction from "additivity" in mixtures of 14.85% KCl solution (A) and 36.75% $CdCl_2$ solution (B). Top: curve drawn by Spacu and Popper [13] without taking experimental errors into consideration.
Bottom: curve drawn from the same experimental data with the minimum possible errors taken into consideration.

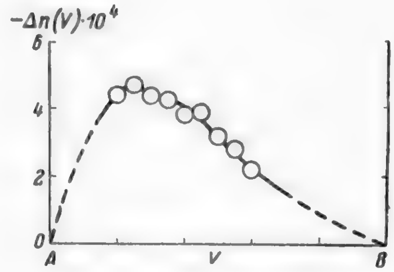

Fig. 2. Deviations of the refractive indices from additivity $\Delta n(V)$ in the same solutions as in Fig. 1, calculated by us from the data of Spacu and Popper [13].

In 1951 the system $CdCl_2 - KCl - H_2O$ was again studied by the refractometric method by N. F. Ermolenko and A. I. Makkaveeva [14]. They used a more accurate (immersion) refractometer for their measurements, in which connection the criterion for the formation of complexes were the deviations of the refractive indices n_D^{20} from additivity as a function of the weight percents of the components (mixed solutions of KCl and $CdCl_2$). The authors of the study found that the curve for the deviations from additivity $\Delta n(P)$ has three maxima, ascribed by them to the compounds $KCl \cdot CdCl_2$, $3KCl \cdot 2CdCl_2$ and $2KCl \cdot CdCl_2$. Although the difference between the maximum and minimum values of Δn on the curve was small $(1- 1.5 \cdot 10^{-4})$, still it was outside the limits of the possible errors that could be incurred when the measurements are made carefully with an immersion refractometer (several 10^{-5} units). Considering the possibility for the existence of several maxima on the curves for the deviations of the refractive indices from additivity to be extremely doubtful in such salt solutions, we decided to again study the system $CdCl_2 - KCl - H_2O$ in the same section that had been studied by H. F. Ermolenko and A. I. Makkaveeva.

EXPERIMENTAL

The solutions were prepared from twice-distilled water and chemically pure potassium chloride and cadmium chloride (Schering-Kahlbaum quality labelled "highest purity, for scientific purposes"). About 460 g of

* The absolute accuracy of the data presented by Spacu and Popper [13] is much lower, and as a comparison of the results for the n_d^{20} of water shows, does not exceed $5 \cdot 10^{-4}$.

16.064% potassium chloride solution (solution A) was prepared from exact amounts of salt and water, weighed on class I technical scales with a correction factor for weighing in the air. The concentration of the cadmium chloride solution was established by trilonometric titration, based on the method of Biedermann and Schwarzenbach [16]. Four determinations gave the amount of $CdCl_2$ (in weight percent) as: 31.924, 31.938, 31.978 and 31.924, and as an average - 31.94 ± 0.02% (solution B). The starting solutions A and B obtained in this manner had nearly the same concentration in mole percent (4.420 mole % KCl and 4.409 mole % $CdCl_2$), and were very close to the concentrations of the solutions used by N. F. Ermolenko and A. I. Makkaveeva [14]. From solutions A and B we prepared (in amounts of 320-350 g, with the correction factor for weighing in the air taken into consideration) two mixed solutions C and D, respectively containing 24.454% and 60.808% of solution B. These solutions (C and D) in turn served as the starting solutions for 18 mixtures, which were prepared in amounts of 23-25 g by weighing solutions C and D on analytical balances with an accuracy of 1 mg in small flasks fitted with ground-glass stoppers. Correction for weighing in the air was not required here, since the densities of solution C and D were sufficiently close.

The described method of preparing the mixtures (in two stages) permitted attaining a comparatively high accuracy of the concentrations with a minimum loss of time for making the weighings and calculations.

The compositions of the starting solutions, their refractive indices and their densities are given in Table 3. The density values (needed to make the calculations of the concentrations) were determined in 20 and 25 ml Byron pycnometers.

TABLE 3

Composition and Properties of the Starting Solutions

Designation	Components from which the solution was prepared	Amount (in wt. %)		n_D^{20}	d_4^{20}
		KCl	$CdCl_2$		
A	Potassium chloride and water	16.06	0.00	1.35493	1.10451
B	Cadmium chloride and water	0.00	31.94	1.39315	1.35988
C	75.55% Solution A + 24.45% solution B	12.14	7.81	1.36233	1.15622
D	39.19% Solution A + 60.81% solution B	6.30	19.42	1.37579	1.24593

A precision Pulfrich-Guild refractometer (see [3], Chapter V) was used to measure the refractive indices of the solutions. The fairly large industrial thermometer on the refractometer was replaced by an ordinary laboratory thermometer, while the eyepiece used to make the readings was fitted with a supplementary diaphragm to reduce errors due to parallax.

A Bobster circulation thermostat was used to maintain the temperature of the measuring prism and solution constant, assuring an accuracy of 0.01-0.02°. An electrical sodium lamp served as the source of monochromatic light.

The refractive index n_D^{20} of each solution was measured twice; the differences in the two measurements did not exceed $1\text{-}2 \cdot 10^{-5}$. The latter value can be considered as being the comparative accuracy of the obtained data. The possible absolute error of the n_D^{20} can be assumed to be $2\text{-}4 \cdot 10^{-5}$.

The experimental values of the n_D^{20} for all of the 22 solutions studied are given in Table 4, as are also the values of the refractive indices calculated as a linear function of the composition of the mixtures expressed in percent on the volume (V) and on the weight (P), and also the corresponding deviations Δn from additivity:

$$n(V)_{\text{add.}} = n_1 \frac{V_1}{100} + n_2 \frac{V_2}{100}, \tag{1}$$

$$n(P)_{\text{add.}} = n_1 \frac{P_1}{100} + n_2 \frac{P_2}{100}, \tag{2}$$

$$\Delta n(V) = n_D^{20} - n(V)_{\text{add.}} \tag{3}$$

$$\Delta n(P) = n_D^{20} - n(P)_{\text{add.}} \tag{4}$$

TABLE 4

Refractive Indices of the Mixtures Containing 16.06% KCl Solution and 31.94% $CdCl_2$ Solution

Designation	Percent $CdCl_2$ solution		Experimental value of n_D^{20}	$n(V)_{\text{add.}}$	$\Delta n(V) \cdot 10^5$	$n(P)_{\text{add.}}$	$\Delta n(P) \cdot 10^5$
	P_1	V_1					
A	0.00	0.00	1.35493	—	—	—	—
B	24.45	20.85	1.36233	1.36290	—57	1.36427	—194
1	26.53	22.68	1.36301	1.36360	—59	1.36507	—206
2	28.47	24.42	1.36367	1.36426	—59	1.36581	—214
3	30.19	26.00	1.36427	1.36487	—60	1.36647	—220
4	32.16	27.80	1.36494	1.36556	—62	1.36722	—228
5	33.99	29.49	1.36559	1.36620	—61	1.36792	—233
6	36.01	31.37	1.36631	1.36692	—61	1.36869	—238
7	37.64	32.89	1.36689	1.36750	—61	1.36932	—243
8	39.67	34.82	1.36763	1.36824	—61	1.37009	—246
9	41.27	36.33	1.36822	1.36882	—60	1.37070	—248
10	43.01	38.00	1.36886	1.36945	—59	1.37137	—251
11	44.85	39.77	1.36955	1.37013	—57	1.37207	—252
12	46.89	41.76	1.37034	1.37089	—55	1.37285	—251
13	48.68	43.52	1.37101	1.37156	—55	1.37354	—253
14	50.44	45.25	1.37168	1.37222	—54	1.37421	—253
15	52.17	46.97	1.37236	1.37288	—52	1.37487	—251
16	54.04	48.84	1.37309	1.37360	—51	1.37558	—249
17	55.67	50.50	1.37373	1.37423	—50	1.37621	—248
18	57.51	52.36	1.37448	1.37494	—46	1.37691	—243
C	60.81	55.75	1.37579	1.37623	—44	1.37817	—238
D	100.00	100.00	1.39315	—	—	—	—

DISCUSSION OF RESULTS

It can be clearly seen from the data of Table 4 and Fig. 3 that in the studied section of the system $CdCl_2 - KCl - H_2O$, contrary to the assertions of earlier investigators, there do not exist three maxima for the deviations of the refractive indices from additivity. Within the limits of possible experimental errors the values $\Delta n(V)$ and $\Delta n(P)$ are expressed by smooth curves, not differing in any essential respect from similar curves in systems the components of which do not form chemical compounds [1, 7]. The maximum deviation from additivity $\Delta n(V)$ is a total of only $6 \cdot 10^{-4}$, i.e., it is smaller than in many systems composed of hydrocarbons and halo derivatives, usually classified with the normal systems. The position of the $\Delta n(V)$ maximum is close to 33 mole % $CdCl_2$ (of the total salts), i.e., it corresponds to a molar ratio of $KCl:CdCl_2 = 2:1$. If the deviations from additivity $\Delta n(V)$ were entirely due to the formation of complexes in the system, then the position of the $\Delta n(V)$ maximum could be interpreted as indicating the presence of the complex K_2CdCl_4 which actually exists in mixed solutions of KCl and $CdCl_2$. However, such small deviations from additivity $\Delta n(V)$, which are present in the system under discussion, could be due to entirely different reasons: the inaccuracy of the additivity rule n(V) itself and expansion, not associated with the formation of compounds of KCl with $CdCl_2$. We believe that in the given case refractometry fails to give an indication either as to the number and composition of the complex compounds present in solution, or as to the very fact of their existence.

The values of $\Delta n(P)$, serving for N. F. Ermolenko and his co-workers [5, 6, 14] as a criterion of the formation of compounds and their composition, in the given system are approximately 4 times greater (in absolute

value) than are the deviations from additivity $\Delta n(V)$. In this connection the $\Delta n(P)$ maximum, as can be seen from Fig. 3, is shifted considerably with respect to the $\Delta n(V)$ maximum toward the $CdCl_2$ side and is situated quite close to the molar ratio $KCl:CdCl_2 = 1:1$. As had already been indicated earlier [7], to relate the values of $\Delta n(P)$ in systems with components of different density only as the result of interaction between the components is without basis. Between the deviations from additivity $\Delta n(V)$ and the values of $\Delta n(P)$ there exists a completely rigid mathematical relationship.

$$\Delta n(P) = \Delta n(V) + (n_1 - n_2)(V_1 - P_1). \qquad (5)$$

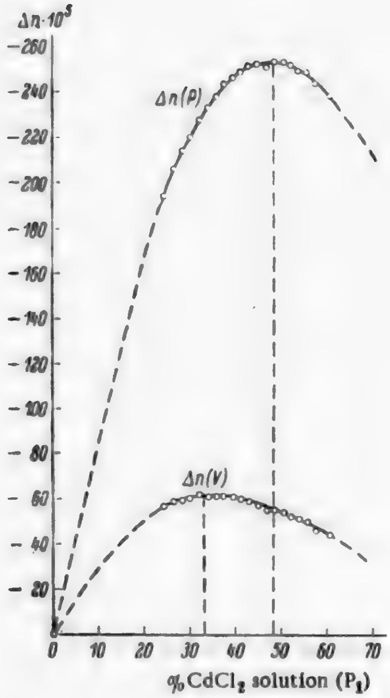

Fig. 3. Deviations of the refractive indices n_D^{20} from additivity in mixtures containing 16.06% KCl solution and 31.94% $CdCl_2$ based on our data.

From this ratio it can be seen that at $n_1 \neq n_2$ and $V_1 \neq P_1$, i.e., when the components have dissimilar refractive indices and densities, the values of $\Delta n(P)$ will be different from zero even in "ideal" systems with $\Delta n(V)=0$. On the other hand, the values of $\Delta n(P)$ can be very small or equal to zero in the systems where the values of $\Delta n(V)$ are large, but are compensated by the term $(n_1 - n_2)(V_1 - P_1)$, having an opposite sign. In the studied system the term $(n_1 - n_2)(V_1 - P_1)$, depending on the ratios of the densities and refractive indices of the components and in no way reflecting their behavior in solutions, is 3-4 times greater than the $\Delta n(V)$ term. As a result, the $\Delta n(P)$ values of $KCl + CdCl_2$ solutions do not reflect interaction of the dissolved salts. Naturally, under such conditions the position of the $\Delta n(P)$ maximum cannot serve as an indication of the composition of the compounds formed in solution. Differentiating [5] with respect to the concentration P_1, we obtain

$$\frac{\partial \Delta n(P)}{\partial P_1} = \frac{\partial \Delta n(V)}{\partial P_1} + (n_1 - n_2)\left(\frac{\partial V_1}{\partial P_1} - 1\right). \qquad (6)$$

From this it can be seen that the derivatives $\frac{\partial \Delta n(P)}{\partial P_1} = \frac{\partial \Delta n(V)}{\partial P_1}$ become equal to zero simultaneously (at a constant concentration) only when $n_1 = n_2$ and $\frac{\partial V_1}{\partial P_1} = 1$. Consequently, a coincidence of the positions of the $\Delta n(P)$ and $\Delta n(V)$ maxima in systems composed of components with different densities and refractive indices can be only accidental.

As can be seen from Fig. 3, the divergence in the positions of the $\Delta n(P)$ and $\Delta n(V)$ maxima in salt solutions can be very great.

SUMMARY

1. The assertions of previous investigators [12-14] that three maxima are present on the curves for the deviations of the refractive indices from additivity in mixed aqueous solutions of potassium and cadmium chlorides are in error and are due to the insufficient accuracy of the experimental data and their incorrect interpretation.

2. By means of accurate measurements it was shown that the isotherms of the refractive indices in the system $CdCl_2-KCl-H_2O$ do not have any characteristics that could be considered as proof that the components form complex compounds.

3. The absence of distinct indications for the formation of compounds on the curves of the refractive indices of the system $CdCl_2-KCl-H_2O$, where complex formation undoubtedly exists, can serve to illustrate the earlier expressed opinion [1-3] that refractometry is not a very sensitive physicochemical analysis method.

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THE VISCOSITY, DENSITY AND BOND ENERGY OF MIXED BINARY SYSTEMS, THE COMPONENTS OF WHICH POSSESS GEOMETRICALLY SIMILAR MOLECULES

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We studied the viscosity and density of the binary systems: benzene-pyridine, toluene-α-picoline, toluene-bromobenzene, α-picoline-bromobenzene, toluene-chlorobenzene, cumene-dimethyl-aniline and stannic chloride-titanium tetrachloride (the last system jointly with A. I. Malinskaya). The components of these systems were chosen on the basis of a similarity in their general configuration and a closeness in the dimensions of their molecules, in the absence of chemical interaction.

On the basis of the obtained data we calculated by the Panchenkov method [1] the values (in calories/mole) of the molecular bond energies of the components and mixtures ϵ_C and the molecular bond energies of the 1st and 2nd components between themselves ϵ_{12}.

The viscosities of the systems toluene-chlorobenzene and toluene-bromobenzene were studied at several temperatures by Yajnik and co workers [2], but the viscosity values presented in their paper for the components of these systems differ sharply from the values given in the literature.

The usual methods were used to purify the substances used in our study. The obtained compounds are characterized by the viscosity and density values that are given below in the tables. The measurements were made at 20, 40 and 60°. The measurement conditions used were similar to those described earlier [3]. The interpolated values of the viscosity and density and the values of ϵ_C and ϵ_{12} calculated on the basis of these data, are presented in Tables 1-7. The mole fractions of the first component are indicated in the tables. The values of the viscosity are expressed in millipoises, and those of the bond energies in cal / mole.

TABLE 1

System Benzene-Pyridine

N	20° η	20° d_4^{20}	40° η	40° d_4^{40}	60° η	60° d_4^{60}	ϵ_C	ϵ_{12}
0.0	9.54	0.9829	7.24	0.9629	5.72	0.9426	2474±27	—
0.2	8.93	0.9615	6.78	0.9414	5.35	0.9211	2470	2469
0.4	8.32	0.9406	6.32	0.9203	4.98	0.8996	2464	2465
0.6	7.70	0.9198	5.85	0.8993	4.61	0.8785	2454	2460
0.8	7.09	0.8992	5.38	0.8783	4.24	0.8572	2442	2450
1.0	6.46	0.8786	4.91	0.8573	3.86	0.8358	2436±35	—

TABLE 2

System Toluene-α-Picoline

N	20°		40°		60°		^{s}C	s_{12}
	η	d_4^{20}	η	d_4^{40}	η	d_4^{60}		
0.0	8.08	0.9419	6.28	0.9236	5.02	0.9046	2299 ± 30	—
0.2	7.60	0.9263	5.93	0.9082	4.76	0.8891	2259	2213
0.4	7.14	0.9113	5.58	0.8929	4.50	0.8738	2213	2214
0.6	6.68	0.8961	5.25	0.8728	4.25	0.8588	2158	2221
0.8	6.24	0.8809	4.94	0.8627	4.02	0.8439	2088	2219
1.0	5.84	0.8657	4.66	0.8479	3.82	0.8294	2010 ± 38	—

TABLE 3

System Toluene-Bromobenzene

N	20°		40°		60°		^{s}C	s_{12}
	η	d_4^{20}	η	d_4^{40}	η	d_4^{60}		
0.0	11.25	1.4937	8.81	1.4676	7.12	1.4410	2235 ± 35	—
0.2	10.01	1.3686	7.86	1.3441	6.34	1.3186	2218	2213
0.4	8.85	1.2431	6.97	1.2202	5.64	1.1962	2179	2192
0.6	7.78	1.1175	6.14	1.0963	4.99	1.0738	2138	2200
0.8	6.77	0.9918	5.37	0.9722	4.37	0.9516	2086	2221
1.0	5.84	0.8657	4.66	0.8479	3.82	0.8294	2010 ± 38	—

TABLE 4

System α-Picoline-Bromobenzene

N	20°		40°		60°		^{s}C	s_{12}
	η	d_4^{20}	η	d_4^{40}	η	d_4^{60}		
0.0	11.25	1.4937	8.81	1.4676	7.12	1.4410	2235 ± 35	—
0.2	10.72	1.3891	8.33	1.3642	6.71	1.3389	2285	2384
0.4	10.16	1.2817	7.85	1.2583	6.31	1.2343	2321	2392
0.6	9.54	1.1709	7.36	1.1492	5.90	1.1269	2342	2408
0.8	8.85	1.0582	6.84	1.0380	5.47	1.0171	2335	2422
1.0	8.08	0.9419	6.28	0.9236	5.02	0.9046	2299 ± 30	—

TABLE 5

System Toluene-Chlorobenzene

N	20°		40°		60°		^{s}C	s_{12}
	η	d_4^{20}	η	d_4^{40}	η	d_4^{60}		
0.0	7.93	1.1064	6.32	1.0847	5.17	1.0628	2053 ± 35	—
0.2	7.51	1.0577	5.97	1.0357	4.88	1.0145	2057	2071
0.4	7.09	1.0082	5.64	0.9881	4.61	0.9675	2061	2084
0.6	6.67	0.9602	5.30	0.9408	4.34	0.9210	2054	2087
0.8	6.26	0.9127	4.98	0.8942	4.07	0.8750	2038	2092
1.0	5.84	0.8657	4.66	0.8479	3.82	0.8294	2010 ± 38	—

TABLE 6

System Cumene-Dimethylaniline

N	20°		40°		60°		ε_C	ε_{12}
	η	d_4^{20}	η	d_4^{40}	η	d_4^{60}		
0.0	14.05	0.9561	10.32	0.9400	7.96	0.9238	2813±19	—
0.2	12.28	0.9357	9.15	0.9197	7.15	0.9033	2671	2438
0.4	10.85	0.9162	8.17	0.9000	6.45	0.8836	2559	2469
0.6	9.63	0.8973	7.33	0.8809	5.86	0.8643	2432	2435
0.8	8.65	0.8790	6.66	0.8625	5.35	0.8457	2337	2434
1.0	7.79	0.8613	6.07	0.8447	4.89	0.8278	2259±29	—

TABLE 7

System Stannic Chloride-Titanium Tetrachloride

N	20°		40°				60°		ε_C	ε_{12}
	η	d_4^{20}	η	η (Panchenkov)	$\Delta\eta$ %	d_4^{40}	η	d_4^{60}		
0.0	8.27	1.7310	7.02	6.95	−1.1	1.7014	5.89	1.6605	1554±70	—
0.2	8.47	1.8340	7.02	7.02	0.0	1.8012	5.91	1.7574	1679	1902
0.4	8.70	1.9351	7.03	7.15	+1.6	1.8990	5.95	1.8527	1762	1879
0.6	8.95	2.0326	7.05	7.30	+3.5	1.9933	6.04	1.9444	1832	1889
0.8	9.22	2.1276	7.09	7.48	+5.4	2.0849	6.16	2.0336	1880	1921
1.0	9.51	2.2201	7.15	7.71	+7.7	2.1740	6.35	2.1202	1880±66	—

TABLE 8

System Chlorobenzene-Bromobenzene

N	ε_C	ε_{12}
0.0	2294±15	—
0.2	2223	2098
0.4	2185	2134
0.6	2130	2101
0.8	2090	2056
1.0	2094±25	—

In addition, based on the data of V. A. Unkovskaya and E. D. Volova [4], we calculated ε_C and ε_{12} for the system chlorobenzene-bromobenzene, the components of which also comply with the above indicated criterion. The results of the calculations are presented in Table 8.

From the tables it can be seen that in all eight systems the relationship between the bond energy of the system and the composition, expressed in mole percent, is a linear one within the limits of experimental error. In all of these systems the volume changes incurred on mixing are very small – a slight contraction is observed.

In the system stannic chloride-titanium tetrachloride the peculiar course of the viscosity isotherm for 40° attracts attention. We calculated the viscosity isotherm at this temperature by the Panchenkov method [1]. The calculation results, presented in Table 7, permit the conclusion that the viscosity dependence of stannic chloride, and of mixtures containing it in substantial amounts, on the temperature is inaccurately described by the Panchenkov equation.

SUMMARY

The viscosity and density of the systems: benzene-pyridine, toluene-α-picoline, toluene-bromobenzene, α-picoline-bromobenzene, toluene-chlorobenzene, cumene-dimethylaniline and stannic chloride-titanium tetrachloride were studied at 20, 40 and 60°. A linear relationship exists between the bond energy of the mixtures and the composition, expressed in mole percent.

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VISCOSITY OF BINARY SYSTEMS WITH CHLORAL. III.

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The present paper is devoted to a study of the viscosity of the binary systems composed of chloral with acetone, methyl ethyl ketone, methyl propyl ketone and acetylacetone. In these systems the viscosity of the mixtures after their preparation does not change, and consequently the measurements were made immediately after the mixtures were prepared. The substances needed for the study were previously dried and distilled. For the study the fractions having the following boiling points were taken: acetone 56.0° at 725 mm, methyl ethyl ketone 78.0° at 730 mm, methyl propyl ketone 99.0° at 730 mm, and acetylacetone 138.0° at 724 mm.

The measurements of the viscosity and density in the system chloral-acetone were made at 25, 35 and 50°. The measurement results are presented in Table 1. The viscosity isotherms for the system chloral-acetone appear as S-shaped curves at all three temperatures. The density isotherms are concave to the composition axis.

In the system chloral-methyl ethyl ketone the viscosity and density were measured at 25, 50 and 75°. The measurement results are presented in Table 2. The viscosity isotherms are concave to the composition axis, while the density isotherms are linear in nature.

In the system chloral-methyl propyl ketone, the same as in the previous system, the viscosity and density measurements were made at 25, 50 and 75°. The measurement results are presented in Table 3. Both the viscosity and density isotherms are linear in nature.

In the system chloral-acetylacetone the viscosity and density were measured at 65, 75 and 85°, and in contrast to the previous systems, the determinations were begun at 85° and terminated at 65°. This transition from a higher to a lower temperature made it possible to achieve supercooling for those mixtures from which a crystalline compound separated. The measurement results are presented in Table 4. The viscosity isotherms, shown in the figure, appear as curves with a singular maximum, found at an equimolar ratio of the components. The singular character of the isotherms is retained at all of the temperatures. The density isotherms are sharply concave to the composition axis.

TABLE 1

System Chloral-Acetone

Amount of chloral (mole %)	Viscosity			Density		
	25°	35°	50°	25°	35°	50°
0.00	0.3214	0.2982	0.2639	0.7864	0.7767	0.7680
7.13	0.4048	0.3678	0.3231	0.8630	0.8516	0.8350
13.71	0.4541	0.4111	0.3615	0.9402	0.9286	0.9122
26.97	0.5494	0.7870	0.4176	1.0624	1.0483	1.0301
37.08	0.6015	0.5376	0.4606	1.1198	1.1060	1.0858
47.23	0.6699	0.5949	0.5118	1.1921	1.1752	1.1560
56.64	0.7342	0.6484	0.5540	1.2547	1.2392	1.2172
65.61	0.7924	0.7021	0.6001	1.3094	1.2958	1.2753
77.31	0.8894	0.7778	0.6568	1.3811	1.3654	1.3426
89.64	0.9679	0.8506	0.7107	1.4474	1.4310	1.4084
100.00	1.0552	0.9017	0.7641	1.5013	1.4859	1.4603

TABLE 2

System Chloral-Methyl Ethyl Ketone

Amount of chloral (mole %)	Viscosity			Density		
	25°	50°	75°	25°	50°	75°
0.00	0.3940	0.3148	0.2595	0.8003	0.7763	0.7553
11.83	0.5125	0.3989	0.3222	0.9045	0.8766	0.8495
20.18	0.5629	0.4323	0.3490	0.9671	0.9402	0.9091
30.06	0.6247	0.4784	0.3815	1.0401	1.0100	0.9781
39.59	0.6758	0.5132	0.4046	1.1080	1.0763	1.0454
50.07	0.7457	0.5619	0.4424	1.1807	1.1488	1.1163
59.79	0.8097	0.6053	0.4772	1.2453	1.2107	1.1766
68.14	0.8541	0.6241	0.4901	1.3074	1.2668	1.2271
75.99	0.8952	0.6588	0.5134	1.3512	1.3135	1.2755
84.70	0.9503	0.7035	0.5391	1.4080	1.3688	1.3293
100.00	1.0552	0.7641	0.5885	1.5013	1.4603	1.4186

TABLE 3

System Chloral-Methyl Propyl Ketone

Amount of chloral (mole %)	Viscosity			Density		
	25°	50°	75°	25°	50°	75°
0.00	0.4591	0.3584	0.2982	0.7994	0.7770	0.7582
11.99	0.5240	0.4084	0.3301	0.8815	0.8565	0.8329
24.89	0.5950	0.4580	0.3660	0.9706	0.9422	0.9163
37.14	0.6722	0.5112	0.4039	1.0539	1.0255	0.9959
50.58	0.7399	0.5571	0.4421	1.1483	1.1176	1.0900
60.71	0.8153	0.6000	0.4686	1.2193	1.1817	1.1466
72.88	0.8727	0.6402	0.5041	1.2930	1.2686	1.2382
81.16	0.9343	0.6822	0.5272	1.3655	1.3271	1.2901
90.01	0.9935	0.7258	0.5574	1.4263	1.3871	1.3588
100.00	1.0552	0.7641	0.5885	1.5013	1.4603	1.4186

TABLE 4

System Chloral-Acetylacetone

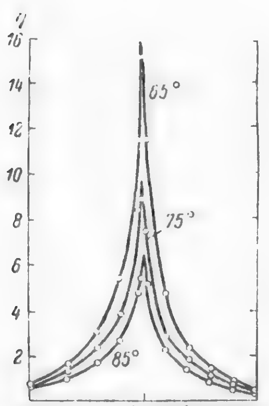
Amount of chloral (mole %)	Viscosity			Density		
	65°	75°	85°	65°	75°	85°
0.00	0.4831	0.4347	0.4212	0.9344	0.9237	0.9133
9.96	0.6992	0.6427	0.5692	1.0125	1.0005	0.9779
19.95	1.1386	0.9894	0.8004	1.0913	1.0797	1.0639
29.97	2.3112	1.8670	1.4012	1.1887	1.1777	1.1665
40.08	4.8743	2.8980	2.2018	1.2625	1.2365	1.2220
48.44	11.557	7.5577	5.1662	1.3427	1.3303	1.3181
50.48	15.207	8.8564	5.3852	1.3678	1.3522	1.3401
51.34	11.552	8.3792	4.7097	1.3700	1.3574	1.3450
59.84	5.4330	3.9168	2.6476	1.4098	1.3934	1.3773
70.00	3.0378	2.3508	1.8529	1.4363	1.4112	1.4082
82.75	1.5324	1.2626	1.0443	1.4388	1.4210	1.3996
100.00	0.6576	0.5885	0.5357	1.4329	1.4186	1.4000

The mixture containing equimolar amounts of the components crystallized completely. The isolated substance is readily soluble in alcohol and acetone, and less readily soluble in benzene, carbon tetrachloride, ether and dichloroethane. After repeated recrystallization from benzene the colorless crystals melted at 79°.

Found %: C 33.78, 34.06; H 3.56, 3.84; Cl 42.85, 42.98. $CCl_3CHO \cdot C_5H_8O_2$. Calculated %: C 33.95; H 3.64: Cl 43.01.

The analysis data correspond to the compound first obtained by Gigli [1].

In analyzing the compound obtained from chloral and acetylacetone, it was established that its composition depends on the duration of its exposure to the air. The cryoscopic determination of the molecular weight in benzene as solvent revealed that the freshly isolated substance has a molecular weight of close to 247, i.e., it corresponds to the molecular weight of the compound $CCl_3CHO \cdot C_5H_8O_2$. The substance that had been kept in the air has a molecular weight lower than 247, in which connection the decrease in molecular weight is proportional to the time of air exposure. Extrapolation of the molecular weight values to infinite dilution for the compound exposed to the air for a long time gave a value of 171. This value is slightly higher than the molecular weight of chloral hydrate, which is equal to 165.4. As a result, it was established that in the compound formed from chloral and acetylacetone the latter can be replaced by water, forming chloral hydrate. In this respect the compounds of chloral with acetylacetone are analogous to the chloral alcoholates , in which one alcohol can be easily replaced by another alcohol [2, 3]. Consequently, it can be expected that in the compounds of chloral with acetylacetone the latter can be replaced not only by water molecules, but also by alcohol molecules.



Viscosity of the system chloral-acetylacetone at 65, 75 and 85°.

After examining the viscosimetric results obtained in studying the system chloral-acetone it can be said that in this system there fails to be any such reaction between the components as would lead to the formation of a new compound. From the literature it is known that in the reaction of chloral with acetone a crystalline compound, chloral acetone, is formed having the composition $CCl_3CHOH \cdot CH_2COCH_3$. But this compound is obtained as the condensation product of chloral with acetone in the presence of acetic acid [4] or of chloral hydrate with acetone in the presence of acetic anhydride [5].

It is known that chloral with alcohols readily forms chloral alcoholates. If keto-enol equilibrium were to exist in pure acetone, then chloral would react with the enol form of acetone which contains a hydroxyl group. Our data show that in the formation of the mixture the components fail to react with each other, and consequently acetone does not convert into the enol form under these conditions. The absence of a hydroxyl group in acetone is also supported by a study of the Raman spectra [6].

From this it follows that the S-shaped form of the viscosity isotherms in this system cannot be explained on the basis of chemical reaction between the components. This form of the viscosity isotherms in the given case must probably be explained by the presence of dipole reaction between chloral and acetone. Under the influence of such electrostatic reaction the molecules of substances can combine to form their own type of complexes, which then exert an influence when the physical properties of binary mixtures are measured [7]. The same can also be said of the systems chloral-methyl ethyl ketone and chloral-methyl propyl ketone.

A different situation prevails in the system chloral-acetylacetone. Here the viscosity isotherms are singular, and the position of the maximum corresponds to the equimolecular compound. The formation of a crystalline compound in this system testifies to the presence of a hydroxyl group in acetylacetone, which reacts with chloral in the same manner as is the case in systems that contain alcohols. However, in contrast to the latter, the presence of a singular maximum on the viscosity isotherms indicates that the compound of acetylacetone with chloral does not enter into reaction with acetylacetone.

SUMMARY

1. The viscosity and density of the system chloral-acetone were measured at 25, 35 and 50°, of the systems chloral-methyl ethyl ketone and chloral-methyl propyl ketone at 25, 50 and 75°, and of the system chloral-acetylacetone at 65, 75 and 85°.

2. In the systems chloral-acetone, chloral-methyl ethyl ketone and chloral-methyl propyl ketone such interaction of the components as would lead to the formation of chemical compounds is absent.

3. A crystalline compound is formed in the system chloral-acetylacetone, the composition of which corresponds to a singular point on the viscosity isotherms.

4. In the equimolecular compound of chloral with acetylacetone the latter can be easily replaced by water.

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PHYSICOCHEMICAL STUDY OF THE REACTION OF TITANIUM TETRACHLORIDE WITH THE ESTERS OF MONOBASIC ACIDS

IX. THE REACTION OF TITANIUM TETRACHLORIDE WITH n-BUTYL CHLOROACETATE AND WITH SOME ESTERS OF TRICHLOROACETIC ACID

Yu. A. Lysenko

In our communications published earlier [1-5], we attempted to elucidate the influence shown by the size of the alcohol and acid radicals in the molecules of monobasic acid esters on their reaction with titanium tetrachloride. We established that titanium tetrachloride, reacting with the esters of monobasic acids, forms in the liquid phase compounds of composition $TiCl_4 \cdot E$ and $TiCl_4 \cdot 2E$ (where E is the ester molecule), in which connection a change in the size of the alcohol and acid radicals in the ester molecules exerts an influence mainly on the formation of compounds of the second type. An increase in the size of the alcohol radical in the case of reacting titanium tetrachloride with esters of acetic acid leads to a reduction in the thermal stability of the $TiCl_4 \cdot 2E$ type of compounds [3]. With decrease in the size of the acid radical in the transition to the esters of formic acid the stability of the $TiCl_4 \cdot 2E$ type of compounds increases somewhat [4].

For further elucidation of the chemical affinity between the examined components it is of interest to study the reaction of titanium tetrachloride with the esters of the chloroacetic acids.

For this purpose we studied the viscosity, density and conductance of the system titanium tetrachloride-n-butyl chloroacetate.

In addition, we studied the viscosity, density and index of refraction of the binary systems: titanium tetrachloride with ethyl trichloroacetate, n-butyl trichloroacetate, isobutyl trichloroacetate and isoamyl trichloroacetate.

The methods used to measure the indicated properties have been described earlier [1, 3].

EXPERIMENTAL

System titanium tetrachloride-n-butyl chloroacetate. The c.p. titanium tetrachloride was not purified further. The n-butyl chloroacetate was synthesized from chloroacetic acid (analytical grade) and n-butyl alcohol. After drying over calcium chloride and fractionation the ester used in our study had b.p. 181.4 – 182°; n_D^{20} 1.4284, d_4^{20} 1.0682.

Preliminary experiments, made with solutions of the given system, revealed that tarring occurs in the system at temperatures above 80°, accompanied by a change in the conductance, while below 72° a rapid formation of crystals is observed. To study the viscosity, density and conductance we selected the temperatures 75 and 80°, at which temperatures the indicated decomposition in the time needed to make the measurements was not observed.

For the purpose of obtaining more reliable data each measurement was repeated by a control determination of the same properties for a freshly prepared solution of the same composition.

All of the points on the diagrams given below for the given system are the average values of the indicated measurements. It should be mentioned that the mixing of the components in preparing the solutions is

accompanied by a substantial heat effect, the same as was the case in the earlier studied systems.

The results of measuring the viscosity, expressed in centipoises, are presented in Fig. 1. The viscosity isotherms pass through a maximum, corresponding to 55 mole % of n-butyl chloroacetate. The curves of the absolute and relative temperature coefficients of the viscosity have a similar form, the maxima of which correspond to the same composition, which permits making the conclusion that the compound $TiCl_4 \cdot ClCH_2COOC_4H_9$ showing dissociation in the liquid phase, is formed.

In Fig. 2 we present only the density isotherm at 75°, since due to the small temperature coefficient the isotherm at 80° nearly merges with the 75° isotherm. Considerable contraction in the region of 40-60 mole % of n-butyl chloroacetate testifies to the chemical affinity between the components, which finds its confirmation on the curve of the molecular volumes.

The isotherms of the conductance (Fig. 3) pass through a maximum, corresponding to 60 mole % of n-butyl chloroacetate. The maximum on the curve of the derived conductance calculated for 75° corresponds to the same composition (Fig. 3).

The curve of the absolute temperature coefficient passes through a maximum corresponding to 55 mole % of n-butyl chloroacetate, which approximates a rational 1:1 ratio of the components. In the region corresponding to an equimolecular ratio of the components there exists a small flat maximum on the curve of the relative temperature coefficient of the conductance.

Our previous studies [3, 4] show that the reaction of titanium tetrachloride with esters in the liquid phase finds its most complete expression on the conductance isotherms, which agrees with the known experimental data. A comparison of all of the properties studied for the given system permits the conclusion that at 75-80° apparently only the compound $TiCl_4 \cdot ClCH_2COOC_4H_9$, showing considerable dissociation in the liquid phase, is formed in the system titanium tetrachloride-n-butyl chloroacetate. It should be mentioned that the maximum conductance for the given system is about 30% of the corresponding conductance values at the same temperatures in the systems titanium tetrachloride-n-butyl acetate and titanium tetrachloride-n-butyl formate [3, 4].

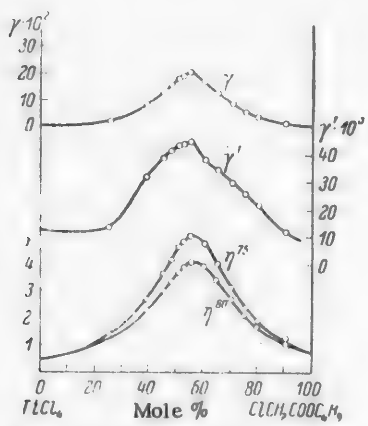

Fig. 1. Isotherms of the viscosity (η), and its absolute (γ) and relative (γ') temperature coefficients, of the system $TiCl_4 — ClCH_2COOC_4H_9$.

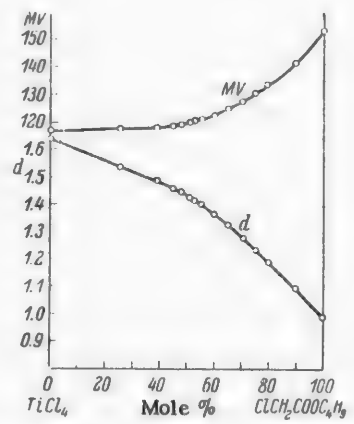

Fig. 2. Density and molecular volume of the system $TiCl_4 — ClCH_2COOC_4H_9$ at 75°.

System titanium tetrachloride-ethyl trichloroacetate. The ethyl chloroacetate was synthesized from c.p. trichloroacetic acid and ethyl alcohol. After drying over calcium chloride and fractional distillation we took for our study the fraction boiling in the range 167.4-167.5°, n_D^{20} 1.4492, d_4^{20} 1.3814.

In contrast to all of the other systems studied by us, formed from titanium tetrachloride and the esters of monobasic acids, we failed to observe any noticeable heat effect when the titanium tetrachloride and ethyl

trichloroacetate were mixed. The prepared solutions are yellow-colored liquids, showing a comparatively low specific conductance ($10^{-6} - 10^{-7} \text{ohm}^{-1} \text{cm}^{-1}$). The measurements were run at 20, 25 and 30°. The viscosity isotherms (Fig. 4) are smooth curves, convex to the composition axes, which permits the conclusion that the components show little chemical affinity in the liquid phase. The isotherms of the densities and molecular volumes, and also the isotherm of the refractive index at 20°, shown in Fig. 5, support the conclusion ensuing from the viscosity measurement results.

However, it should be mentioned that the cooling of solutions, containing the components in approximately equimolar amounts, results in the separation of yellow crystals. This observation permits the assumption that considerable dissociation of the formed compounds into the starting components occurs in the studied system at 20-30°.

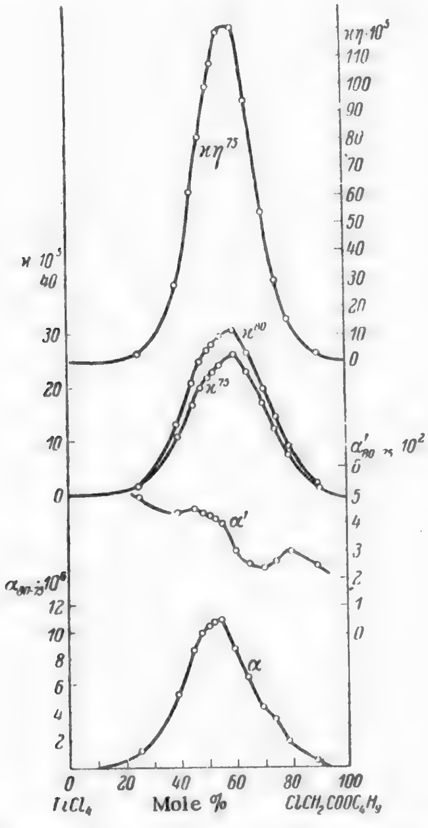

Fig. 3. The conductance (κ), derived conductance, and the relative (α') and absolute (α) temperature coefficients of the conductance of the system $TiCl_4 - ClCH_2COOC_4H_9$.

System titanium tetrachloride-n-butyl trichloroacetate. The n-butyl trichloracetate was synthesized from c.p. trichloroacetic acid and n-butyl alcohol, after which it was dried over calcium chloride and fractionally distilled. For our study we used the fraction with b.p. 204.5 – 205.0°, n_D^{20} 1.4508, d_4^{20} 1.2723.

Mixing the components in the preparation of the solutions is not accompanied by a noticeable heat effect. The solutions are colored yellow and have a conductance of the same order as for the previous system. The measurements were run at 20, 25 and 30°. The data on the viscosity (Fig. 6) show that in this system chemical reaction between the components in the liquid phase is lowered substantially. This finds confirmation in the results of measuring the densities and refractive indices, shown in Fig. 7. The isotherms of the densities at 20 and 30°, of the refractive indices at 20°, and of the molecular volumes and mole fractions, calculated for 20°, represent curves that are slightly concave to the composition axes. We failed to observe the formation of crystals when the solutions were cooled to – 15°.

System titanium tetrachloride-isobutyl trichloroacetate. The isobutyl trichloroacetate used in the study was prepared and purified as described above, and had m.p. 196.3 — 196.5°, n_D^{20} 1.4470, d_4^{20} 1.2618.

A noticeable heat effect on mixing the components was not observed. The prepared solutions had a yellow color and their conductance was of the order $10^{-6} - 10^{-7}$ ohm^{-1} cm^{-1}.

The results of measuring the viscosity at 20, 25 and 30°, depicted in Fig. 8, and the data on measuring the density and refractive index, shown in Fig. 9, permit making the same conclusion as for the other systems described above.

However, it is necessary to mention that the separation of yellow crystals is observed when the temperature of those solutions in which the content of the components is close to the composition of the 1:1 compound is lowered to 0°.

System titanium tetrachloride-isoamyl trichloroacetate. The isoamyl trichloroacetate used in the study was synthesized and purified in the same manner as indicated for the previous systems. The fractions used in the study had b.p. 217 — 217.8°, n_D^{20} 1.4490, d_4^{20} 1.2300.

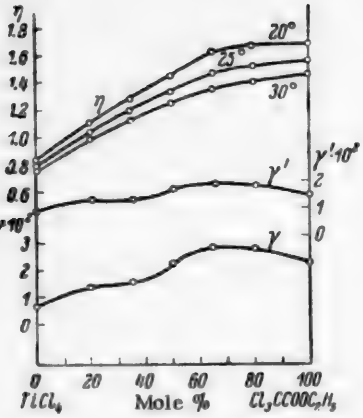

Fig. 4. Viscosity and its relative and absolute temperature coefficients of the system $TiCl_4 - Cl_3CCOOC_2H_5$.

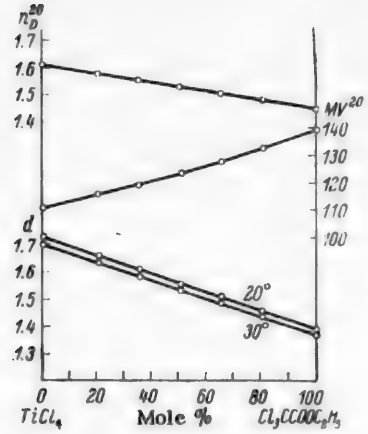

Fig. 5. Density, molecular volume and index of refraction of the system $TiCl_4-Cl_3CCOOC_2H_5$.

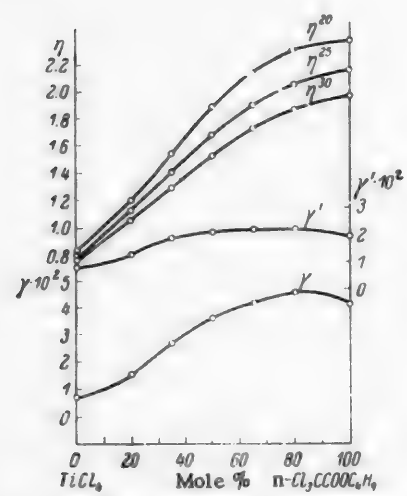

Fig. 6. Viscosity and its relative and absolute temperature coefficients of the system $TiCl_4$ –n-Cl_3 $CCOOC_4H_9$.

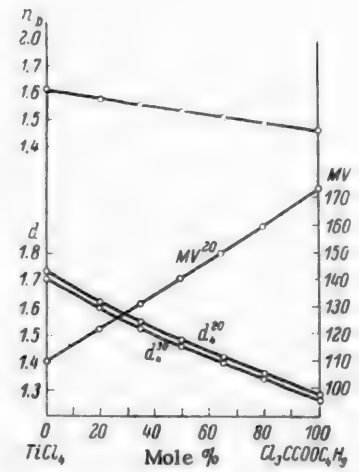

Fig. 7. Density, molecular volume and index of refraction of the system $TiCl_4$– n -$Cl_3COOC_4H_9$.

The mixing of the components was not accompanied by any noticeable heat effect. The color of the solution was yellow. The magnitude of the specific conductance varied in the same range as for the solutions of the above described systems.

The data on the viscosity at 20, 25 and 30°, depicted in Fig. 10, lead to the conclusion that substantial chemical affinity between the components is absent in the given system. The isotherms of the density at 20 and 30°, depicted in Fig. 10, lead to the conclusion that substantial chemical affinity between the components is absent in the given system. The isotherms of the density at 20 and 30° and of the molecular volume,

calculated for 20° (Fig. 11), represent curves that are slightly concave to the composition axes. The shape of the index of refraction isotherms at 20° also leads to the conclusion of weakened chemical reaction between the components. The separation of crystals was not observed when the solutions were cooled to 20°.

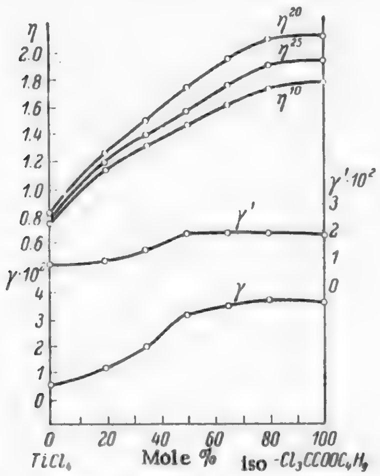

Fig. 8. Viscosity and its relative and absolute temperature coefficients of the system $TiCl_4$ — iso-$Cl_3CCOOC_4H_9$.

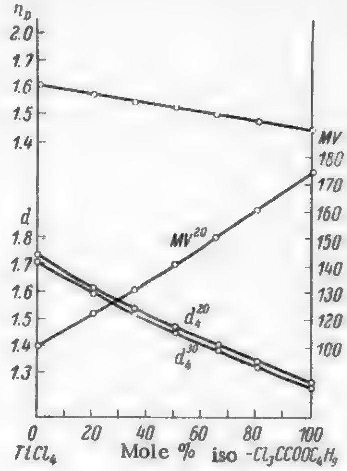

Fig. 9. Density, molecular volume and index of refraction of the system $TiCl_4$–iso-$Cl_3CCOOC_4H_9$.

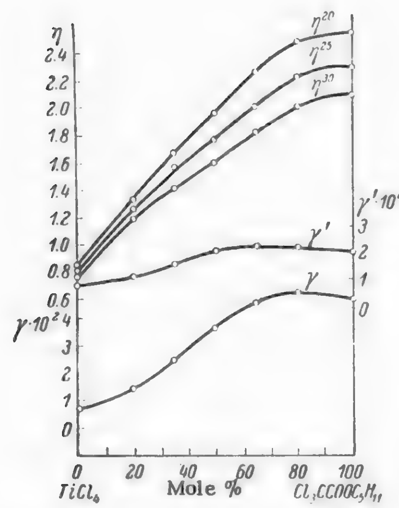

Fig. 10. Viscosity and its relative and absolute temperature coefficients of the system $TiCl_4$ $Cl_3CCOOC_5H_{11}$.

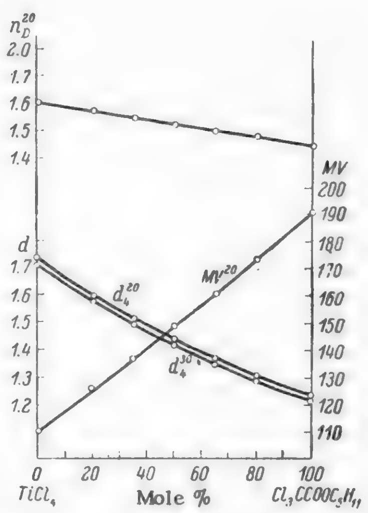

Fig. 11. Density, molecular volume and index of refraction of the system $TiCl_4$–$Cl_3CCOOC_5H_{11}$.

As had been established by us [3], in the system titanium tetrachloride-n-butyl acetate at 70-80° there occurs the formation of two compounds, $TiCl_4 \cdot CH_3COOC_4H_9$ and $TiCl_4 \cdot 2CH_3COOC_4H_9$, of which the second is strongly dissociated in the liquid phase. The present study shows that at 75-80° a dissociated compound of composition $TiCl_4 \cdot ClCH_2COOC_4H_9$, is formed in the system titanium tetrachloride-n-butyl chloroacetate, in

which connection we were unable to show the formation of the second compound $TiCl_4 \cdot 2ClCH_2COOC_4H_9$ by any of the physicochemical methods employed by us.

A study of the system titanium tetrachloride-n-butyl trichloroacetate and of the other systems studied by us, formed from titanium tetrachloride and the esters of trichloroacetic acid, leads to the conclusion of weakened chemical reaction between the components of these systems, as a result of which the compounds formed in the indicated systems prove to be considerably dissociated into the starting components at 20-30°.

As a result, from a comparison of the obtained results and the data of the previous investigations [3] it can be concluded that an increase in the electrophilic properties of the acid radical in ester molecules substantially weakens their reactivity with titanium tetrachloride.

SUMMARY

1. Based on the measurements of the viscosity, density and conductance at 75 and 80° for the system titanium tetrachloride-n-butyl chloroacetate it was established that a compound of equimolar composition is formed, showing dissociation in the liquid phase.

2. In the systems titanium tetrachloride-ethyl trichloroacetate, titanium tetrachloride-n-butyl trichloroacetate, titanium tetrachloride-isobutyl trichloroacetate and titanium tetrachloride-isoamyl trichloroacetate a considerable weakening of chemical interaction between the components in the liquid phase was observed due to the increase in the electrophilic properties of the acid radical in ester molecules.

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METHOD FOR THE DETERMINATION OF THE ACTIVITY OF SKELETAL NICKEL CATALYST WITH THE AID OF THE CEMENTATION REACTION

A. I. Kryagova

According to the literature, there exist various methods for controlling the activity of catalysts. These methods can be either direct or indirect. The direct method most frequently used in practice to determine the activity of a hydrogenation catalyst is to determine the rate of the hydrogenation process.

One of the indirect methods for determining the activity of a catalyst is based on its pyrophoric properties. The pyrophoric nature of skeletal nickel catalyst is conditioned by the presence of hydrogen, which determines the structure of the catalyst surface, and consequently its amount should also be found in direct relationship to the activity of the catalyst.

Earlier it had been shown [1] that the potentiometric method of studying powdered catalysts permits determining the degree of change in the hydrogen concentration on a catalyst surface during the reaction process, and consequently, also, the degree of its activity.

In a number of cases the activity of a catalyst can also be indirectly determined by its dispersibility. According to the data of A. M. Rubinshtein [2], there exists a definite relationship between the size of the grains in a powdered catalyst and its catalytic activity, which, however, is not always observed. Thus, for example, very frequently a decrease in activity is observed when the dispersibility of a catalyst is increased. In connection with this, for each hydrogenation process there probably exists an optimum dispersibility of the catalyst, corresponding to its maximum activity, and this relationship can be established only experimentally.

From practice it is well known that not only the dispersibility, but also the secondary structure (clumps, aggregates, etc.) exert essential influence on the activity of a catalyst.

In studies [3-7] it was shown that only the contemporary electron-microscope method makes it possible to study the peculiar secondary structure of a catalyst and to follow its profound structural changes with time. The use of a number of methods in conjunction with each other proves to be especially fruitful. To obtain the most complete characterization of a catalyst, a coupling of the x-ray and electron-microscope study methods with the adsorption and catalytic methods is recommended. Other methods can also be used to manifest the active surface of a catalyst: the differential isotopic [8], magnetic [9], and other methods.

The activity of a catalyst can also be characterized by the properties of the product obtained in the hydrogenation process. Thus, for example, according to the data of [10], the activity of the catalyst used in the hydrogenation was characterized by the melting point of the fatty mass obtained in the hydrogenation.

In the present study we propose a simple and rapid method for the determination of the activity of a skeletal nickel catalyst that is based on the rate with which copper ions are displaced from copper sulfate solution by nickel powder. This reaction, usually known as the cementation reaction, is the subject of a number of papers [11-19].

To study the properties of a skeletal nickel catalyst we studied some commercial specimens* of different activity.

* Based on the chemical and spectral analysis data, obtained by the author, the catalyst is essentially pure nickel.

EXPERIMENTAL

The cementation reaction was run with heating and mechanical stirring in 600 to 1000 ml beakers. For the experiment 400 ml of copper sulfate solution, containing 14 g/liter of copper and 2.25 g/liter of sulfuric acid, was poured into a beaker. The solution was heated to 75 ± 1°. The powdered nickel catalyst was dried between filter paper and weighed on technical scales (weight 5 g).

In order always to assure obtaining reproducible results, it was necessary rapidly to dry the catalyst under identical conditions (but not to the point of flashing). The weighed catalyst was introduced into the heated copper sulfate solution and then stirring was started immediately. The intensity of stirring was such that the powdered nickel catalyst was always found as a suspension. The duration of the cementation reaction was 30 minutes. Samples of the solution were removed at definite intervals for analysis. Copper was determined idometrically. Experiment revealed that the more active the catalyst, the less the hindering effect of the cementing copper film on the reaction course.

If it is assumed that chemical factors play an essential role in the cementation reaction, then the elements (Ni and Cu) should react with each other in equivalent amounts. Assuming the introduction of a definite amount of nickel catalyst into copper sulfate, it becomes possible to calculate in advance the amount of displaced copper under the conditions that the displacement reaction proceeds by the equation $CuSO_4 + Ni = NiSO_4 + Cu$, in accord with which 58.69 g of nickel is capable of displacing 63.54 g of copper; if we start with a weight of 5 g nickel catalyst, then the amount of displaced copper should be equal to 5.415 g, and consequently the amount of copper in the volume of the starting solution should exceed this value, for which reason we took 5.6 g instead of 5.415 g of copper in 400 ml of the starting solution. The activity of a nickel catalyst with respect to the cementation reaction can be determined by the formula

$$A = \frac{(a - b) \cdot 58.69 \cdot 100}{c \cdot 63.54},$$

where A is the activity of the catalyst (in %), a is the amount of copper in the starting copper sulfate solution, b is the amount of copper in the copper sulfate solution after experiment, c is the weight of catalyst, 58.69 is the atomic weight of nickel, and 63.54 is the atomic weight of copper.

TABLE 1

Specimen No.	Activity of catalyst (in %)	Characterization of the catalysts for hydrogenation
1	10.2	Spent (dry)
2	26.5	Spent (moist)
3	65.1	Fresh (moist), after several hydrogenations

Not all of the nickel in the catalyst, but only the active portion of its surface, participates in the cementation reaction, and consequently the activity of the catalysts is not always equal to 100% (Table 1).

As was established by experiment, the best method for the removal of samples from the copper sulfate solution was by decantation. Within 3-4 minutes after turning off the stirrer the powdered nickel catalyst had completely settled on the bottom of the beaker.

Using the developed method, we studied some commercial catalyst samples. The results obtained for the various catalysts are summarized in Table 2. The accuracy of the determinations was 2-3%. The data in Table 2 show that in one hydrogenation the fresh catalyst is reduced in activity by approximately 10-20%.

It is necessary to indicate that the activity of a catalyst is reduced on long standing due to coarsening of the nickel grains, oxidation of its surface, and in all probability, hydrogen desorption. This circumstance should be taken into consideration in preparing catalysts under plant conditions, as a result of which it is not recommended to prepare large amounts of catalyst for storage.

TABLE 2

Specimen No.	Activity of catalyst (in %)	Characterization of the moist catalysts for hydrogenation
4	100.0	Fresh
	84.0	Fresh, after one hydrogenation
5	100.0	Fresh
	89.2	Fresh, after one hydrogenation
6	99.7	Fresh
	30.1	Fresh, after several hydrogenations
7	71.8	Fresh
	50.9	Fresh, after one hydrogenation
8	34.6	Spent catalyst
9	26.5	Spent catalyst

SUMMARY

1. A method for the determination of activity of a skeletal nickel catalyst with the aid of the cementation reaction was proposed. It was experimentally shown that the more active the catalyst, the greater the extent to which it displaces copper ions from a copper sulfate solution in a given length of time. We established the optimum conditions for running this reaction.

2. A formula was proposed for calculating the activity of skeletal nickel catalysts.

3. It is possible to classify catalysts into three groups, a) catalysts of high activity ranging from 100 to 70%, b) catalysts of average activity ranging from 70 to 40%, and c) spent catalysts with an activity of 40% and less.

4. The division of skeletal nickel catalysts into groups and the method of determining the activity can give a definite answer to the question of the relationship between the time of hydrogenating a product and the activity only if identical conditions are observed in the processes of leaching, hydrogenation, etc.

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THE REACTION OF NITROUS ACID WITH SALICYLIC ACID IN ACETIC ACID MEDIUM

A. A. Nemodruk

A method is described in the literature for the preparation of nitrososalicylic acid by the nitrosation of salicylic acid in acetic acid using sodium nitrite [1]. However, P. Friedländer has expressed doubt that nitrososalicylic acid is formed in the given case [2].

Later, W. Lesniansky showed that the nitrosation of salicylic acid under these conditions does not lead to the formation of nitrososalicylic acid [3]. From the reaction products he was able to isolate only o-nitrosophenol in about 0.5% yield.

Nevertheless, later V. G. Gulinov communicated that he was able to obtain nitrososalicylic acid under the indicated conditions in 76% yield [4].

In studying the reaction of nitrous acid with salicylic acid in acetic acid medium we found that the formation of nitrososalicylic acid does not occur under these conditions, and consequently the studies indicating its formation are in error [1, 4].

The main reaction product is o-diazophenol, the yield of which reaches about 20%. We also found o-nitrosophenol in the reaction products, the yield of which was about 0.9%, based on salicylic acid. In addition, we were able to isolate 74% of unreacted salicylic acid from the reaction mixture.

If the amount of sodium nitrite is increased to 5 moles per mole of salicylic acid, then o-diazophenol is formed in greater than 88% yield. At the same time o-diazophenol is formed in greater than 88% yield. At the same time o-nitrosophenol is absent. This gives basis to assume that in the first stage of the reaction of nitrous acid with salicylic acid the formation of o-nitrosophenol apparently occurs with the liberation of carbon dioxide.

Further reaction of nitrous acid with the formed o-nitrosophenol leads to obtaining o-diazophenol, the same as occurs in other similar cases [5-9].

In support of such a reaction course is the smooth transformation of o-nitrosophenol into o-diazophenol under the same conditions.

The rate for the formation of o-diazophenol from o-nitrosophenol is considerably greater than is the formation rate of the latter from salicylic acid. As a result of this, the amount of o-nitrosophenol in the reaction mixture is small, and toward the end of reaction it is completely converted into o-diazophenol.

The preparation of o-diazophenol by the treatment of salicylic acid with nitrous acid in acetic acid medium possesses considerable advantages over the other known methods basically in the simplicity of the method and availability of the starting products.

EXPERIMENTAL

To 16 g of sodium salicylate and 7.5 g of sodium nitrite, dissolved in 800 ml of water, was added in drops 100 ml of glacial acetic acid in 1-2 hours. The mixture was let stand at 20° for 48 hours. At the end of this time the presence of nitrous acid in the solution could not be shown. Azo compounds are formed when the solution is reacted with an alkaline solution of resorcinol and 1,8-aminonaphthol-3,6-disulfonic acid.

The Hantzsch method [10] was used to determine quantitatively the amount of formed diazo compound, For this the solution was made up to a volume of 1000 ml (solution A), and 25 ml aliquots were taken for each determination. The yield of diazo compound was 20.8%, based on sodium salicylate.

Using the known qualitative test [11], it was established that the nitroso compound is also present in the reaction products.

For the quantitative determination of the nitroso compound 25 ml of solution A was neutralized with soda and coupled with 0.3 g of resorcinol, dissolved in 10 ml of 10% soda solution. The nitroso compound and the formed azo compound were titrated with a solution of bivalent vanadium sulfate [12]. Since the nitroso compound and the azo compound have the same equivalents, from the obtained total we obtain the amount of nitroso compound by substracting the previously determined amount of diazo compound. The yield of the nitroso compound was 0.9%.

The nitroso compound was extracted from the reaction mixture with gasoline. After evaporation of the benzine the residue was treated with 50 ml of 12.5% copper sulfate solution. The resulting dark-red precipitate was dissolved in 10 ml of sulfuric acid and again extracted with gasoline. Removal of the gasoline by evaporation left a greenish-yellow crystalline substance, which on the basis of the analysis results and qualitative reactions was identified as o-nitrosophenol.

By evaporating 50 ml of solution A in vacuo and dissolving the dry residue in 15 ml of water we were able to isolate the unreacted salicylic acid, the amount of which was 74%.

An increase in the amount of sodium nitrite taken for reaction leads to an increase in the yield of the diazo compound. The best results were obtained when the amount of sodium nitrite introduced under the indicated conditions was 35 g. In this case 50 ml of concentrated hydrochloric acid was added after 48 hours, and the unreacted nitrous acid was removed by the addition of sulfamic acid. Then the amounts of diazo compound and nitroso compound were determined by the already described method. The yield of the diazo compound under these conditions was 88.2%. The nitroso compound was absent.

Based on the color reactions of the azo-coupling products the diazo compound was identified as o-diazophenol. Its decomposition with cuprous chloride gave o-chlorophenol with b.p. 175° (756 mm) and f.p. 7°.

In support of the entrance of a nitroso group for the carboxyl is the evolution of CO_2 during the reaction process. The CO_2 was trapped by passing the evolved gases through a potash apparatus containing KOH solution and then determined by precipitation as $BaCO_3$. The obtained data show that the carboxyl group is cleaved to the extent of 96%.

To a solution of 0.61 g of o-nitrosophenol, obtained according to [13], in 40 ml of water was added 1.7 g of $NaNO_2$ and 5 ml of glacial acetic acid. After 24 hours 2.5 ml of concentrated hydrochloric acid was added and the excess nitrous acid was removed by the addition of sulfamic acid. The yield of the diazo compound was 93.2%, based on nitrosophenol. o-Nitrosophenol was absent in the reaction mixture.

SUMMARY

It was shown that the reaction of salicylic acid with nitrous acid in acetic acid medium does not lead to the formation of nitrososalicylic acid. Instead, the nitroso group enters the salicylic acid molecule with the removal of CO_2 and the formation of o-nitrosophenol, which as the result of further reaction with nitrous acid is converted into o-diazophenol, which is main reaction product. The yield of o-diazophenol when the amount of sodium nitrite is increased to 5 moles per mole of salicylic acid is 88%.

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SYNTHESES WITH COMPLEX COMPOUNDS

III. THE PREPARATION OF AZO COMPOUNDS FROM CHROMOTROPIC ACID AND OTHER 1,8-DIHYDROXYNAPHTHALENE SULFONIC ACIDS

V. I. Kuznetsov and A. A. Nemodruk

The absence of a clear and convincing comparison of the mechanism for the azo-coupling of polyphenols or polynaphthols with the mechanism for their oxidation did not permit showing a difference in these mechanisms.

However, this difference is clearly shown when the progress of both processes with cyclic salts is studied. When these salts show well-developed intramolecular dissociation [1], they readily react with diazo compounds, forming azo compounds. The progress of the oxidation processes, even in alkaline medium, proves to show a parallelism. This circumstance makes it possible to effect substantial improvement in the techniques used to synthesize a number of azo compounds from chromotropic acid and its analogs.

The synthesis of some azo compounds from 1,8-dihydroxynaphthalene and its sulfonic acids is complicated by the fact that in the case of diazo compounds of low activity the azo-coupling practically fails to go in acid medium, while in alkaline medium simultaneously with azo-coupling there proceeds the secondary process of oxidizing the azo components by diazo compounds [2].

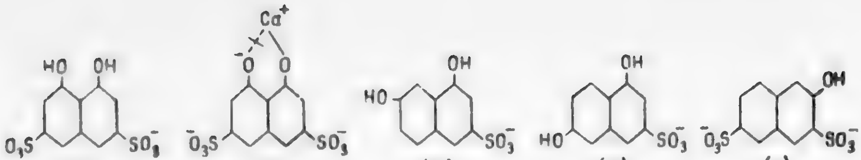
With some of the diazo compounds of low activity this secondary process in general does not permit obtaining azo-coupling to any large degree. In this case the circumstances add up to the same situation that prevails in the earlier examined synthesis of azo compounds from pyrocatechol [3]. In addition, in alkaline medium chromotropic acid and many other sulfonic acids of 1,8-dihydroxynaphthalene are rapidly oxidized by atmospheric oxygen, which introduces known difficulties. The use of cyclic salts for the purposes of synthesizing azo compounds permits eliminating all of these difficulties. The oxidation by atmospheric oxygen and diazo compounds proves to be suppressed, while at the same time the azo-coupling proceeds without any difficulties.

Since the ability of elements to form cyclic compounds with a manifested intramolecular dissociation at a given concrete pH value can be easily predicted on the basis of theoretical considerations [1], then no difficulties are involved either in selecting the most suitable element or in choosing the conditions for running the azo-coupling.

When the azo-coupling is run in alkaline medium the cyclic salts of those elements are suitable whose cations do not hydrolyze in neutral medium, i.e., the salts of calcium, strontium, barium and magnesium. The readily available calcium salts are of interest for the commercial synthesis of azo dyes.

A number of recommendations can be found in the literature relative to running the azo-coupling reaction in the presence of calcium, magnesium, strontium or zinc salts [4]. However, the mechanism for the action of these additions is not elucidated. The obscure nature of the mechanism makes it impossible to have a thorough knowledge of the direction of the process.

On the other hand, if based on the hypotheses for the intramolecular dissociation of cyclic salts, the mechanism becomes quite clear. This is supported by the fact that chromotropic acid (I), capable of forming cyclic salts, under the conditions manifested by them for intramolecular dissociation (II), is



(I) (II) (III) (IV) (V)

coupled with ease and oxidized with difficulty in the presence of the salts of the indicated elements. At the same time the addition of the salts of calcium, magnesium and other elements fail to exert noticeable influence on the azo-coupling of 1,7-dihydroxynaphthalene-3-sulfonic acid (III), 1,6-dihydroxynaphthalene-3-sulfonic acid (IV) or 2-hydroxynaphthalene-3,6-disulfonic acid (V), compounds that are incapable of forming cyclic salts.

For known reasons [1] the cyclic aluminum salt of chromotropic acid fails to show intramolecular dissociation in alkaline medium and couples with diazo compounds with considerably greater difficulty than does chromotropic acid itself under these conditions. On the other hand, the cyclic aluminum salt of chromotropic acid is capable of azo-coupling in weakly acid medium, and the cyclic zirconium salt of chromotropic acid in strong mineral acid solutions, where the coupling of weakly active diazo compounds with chromotropic acid is practically nonexistent.

The use of cyclic salts is also beneficial in the preparation of bisazo compounds from 1,8-dihydroxynapthalene and its derivatives. The synthesis of bisazo compounds, especially from diazo compounds of low activity and chromotropic acid or other 1,8-dihydroxynaphthalene derivatives, not found in the form of cyclic salts, for these reasons proceeds with difficulty or doesn't go at all. The bisazo compounds are synthesized without any difficulties when the cyclic salts are used.

EXPERIMENTAL

1. Acid Sky Blue S [1-N, N-Dimethylaminobenzene-(4-azo-7)-1,8-dihydroxynaphthalene-3,6-disulfonic Acid, Disodium Salt].

Cyclic calcium salt of chromotropic acid. To a solution of 2.0 g of sodium hydroxide and 17.1 g (0.050 mole) of the monosodium salt of chromotropic acid in 100 ml of water was added either milk of lime or a paste, corresponding to 6.7 g of $Ca(OH)_2$ (or a mixture of calcium chloride and sodium hydroxide), and the mixture was stirred for 1 hour.

Preparation and isolation of the dye. A solution of 17.8 g (0.050 mole) of technical double zinc salt of 4-diazodimethylaniline, calculated as 100% pure substance, in 80 ml of water was neutralized with sodium hydroxide to slightly alkaline reaction, and then the cyclic calcium salt of chromotropic acid was added to the solution. After 2-hour stirring and heating to 60° the mixture was treated with 10 g of calcined soda to precipitate the calcium completely. The calcium carbonate precipitate was filtered and washed with 25 ml of water. The filtrate was treated with 25 ml of hydrochloric acid (d 1.14) and 50 g of common salt. The dye precipitate was filtered and dried. The yield was about 35 g. The azo compound content, determined by titration with bivalent vanadium sulfate [5], was 44.7%. Yield 90%.

When synthesized in the usual manner [6] the yield of the dye is 58%.

The shades of the dye obtained using the calcium salt are characterized by a purer hue.

The curves for the light absorption of aqueous solutions of the dye obtained in the usual manner, for a solution of 4 mg of the dye in 100 ml of water (Curve a), and of the dye obtained through the cyclic calcium salt of chromotropic acid, for a solution of 3.2 mg of dye in 100 ml of water (Curve b), with a layer thickness of 10 mm, are compared in Fig. 1.

2. Acid Chrome Blue K [1,4-Phenolsulfonic Acid-(2-Azo-7)-1,8-dihydroxynaphthalene-3,6-disulfonic Acid, Trisodium Salt].

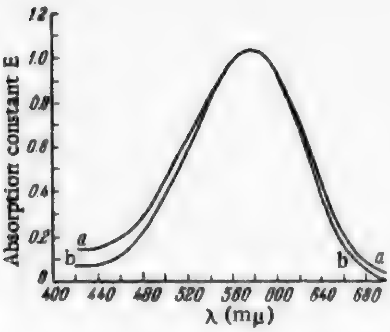


Fig. 1.

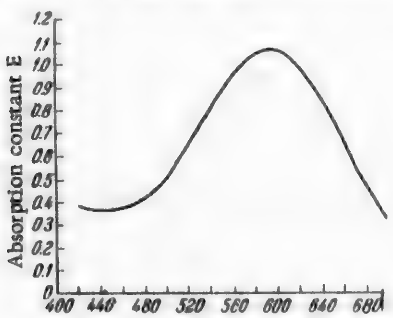
A solution of 10 g (0.050 mole) of 1-diazo-2-phenol-5-sulfonic acid, obtained by the method of Rodionov and Matveeva [7], in 50 ml of water was neutralized with 10% soda solution and then added to a solution of the cyclic calcium salt of chromotropic acid, prepared the same as in Section 1. After stirring for 2 hours, the calcium was precipitated and the dye isolated in the same manner as described in Section 1. The yield of 50.6% product was 48.6 g (84%). When prepared in the usual manner [6] the yield of the dye fails to exceed 55%.

3. Direct Sky Blue S [Copper Complex of 3,3'-Dihydroxydiphenyl-4,4'-bis-(7-azo-1,8-dihydroxynaphthalene-3,6-disulfonic Acid), Tetrasodium Salt].

A stirred suspension of 7.9 g (0.025 mole) of o-dianisidine hydrochloride in 100 ml of water was treated with 6 ml of concentrated hydrochloric acid and about 50 g of ice, and then diazotized with a solution of 3.5 g of sodium nitrite in 10 ml of water. The diazo solution was neutralized with 10% soda solution and then added to a solution of the cyclic calcium salt of chromotropic acid, prepared as described in Section 1. After stirring for 2 hours the mixture was diluted with water to a volume of 0.5 liter, heated to 95-98°, 10 g of calcined soda added, and the calcium carbonate precipitate removed by filtration. The precipitate was washed with 25 ml of water. The filtrate was treated with 30 ml of hydrochloric acid (d 1.14) and the cuprammonium solution, prepared by dissolving 14 g of copper sulfate in 40 ml of 20% ammonia solution and 25 ml of water, and then kept at 95-98° for 5 hours. The dye was isolated by the addition of 65 g of common salt, filtered, and dried at 120-125°. The yield of 66% product was 37 g (90%), which is 30% greater than the yield obtained when operating without the calcium salt. At the same time the quality of the dye is improved.

4. 4-Methoxydiphenylamine-(4'-azo-7)-1,8-dihydroxynaphthalene-3,6-disulfonic Acid, Disodium Salt.

A stirred suspension of 10.7 g (0.050 mole) of technical 4-diazo-4'-methoxydiphenylamine, taken as 100% pure, in 125 ml of water was neutralized with soda solution until weakly alkaline, and then added to a solution of the cyclic calcium salt of chromotropic acid, prepared in the same manner as in Section 1. After stirring for 4 hours, 10 g of soda was added, and the calcium carbonate precipitate was filtered and washed with 25 ml of water. The addition of 50 g of common salt and 25 ml of hydrochloric acid (d 1.14) to the filtrate gave the azo compound as a precipitate, which was filtered and dried. The yield of 65.1% product was 34 g (74%). The dye was a dark-blue powder. It dissolves in water, acetic acid and in 1N hydrochloric acid with a sky blue color. It dissolves in soda solution with a violet color, and in 1N sodium hydroxide solution with a pink color. It dyes wool a sky blue color. The light-absorption curve for a solution of 5.6 mg of the product in 100 ml of water at a layer thickness of 10 shows a maximum at 590 m (Fig. 2).



(Fig. 2.)

The synthesis of this compound cannot be achieved without using the cyclic salts of chromotropic acid.

5. Diphenylamine-2-sulfonic Acid-(4-Azo-7)-1,8-dihydroxynaphthalene-3,6-disulfonic Acid, Trisodium Salt.

A stirred suspension of 14 g (0.050 mole) of 4-aminodiphenylamine-2-sulfonic acid, taken as 100% product, in 35 ml of 18% hydrochloric acid was treated with 50 g of ice and then diazotized with a solution of 6 g of sodium nitrite in 20 ml of water. After 1 hour the excess nitrous acid was removed by the addition of sulfamic acid. The diazo compound was neutralized with soda to weakly alkaline reaction and then added to a solution of the cyclic calcium salt of chromotropic acid, prepared in the same manner as before. The remainder of the procedure was the same as in the previous example. The yield of 67.5% product was 40 g (81.8%). The dye, a dark-blue powder, dissolves in water with a sky blue color, in 1N sodium hydroxide solution with a pink color, in soda solution with a violet color, and in acetic and hydrochloric acids with a sky blue color.

Wool is dyed a blue color by the dye. The color turns to a green when the dyed fabric is subsequently treated with potassium bichromate. The dye fails to dye cotton fabric.

When the azo-coupling is run in soda-alkali medium with free chromotropic acid, and not as the cyclic salt, the yield drops to 52.2%.

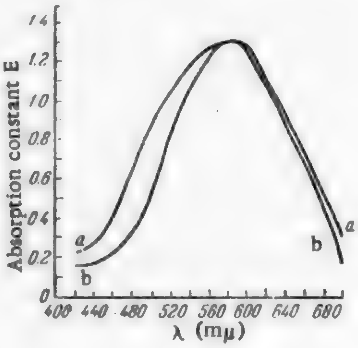


Fig. 3.

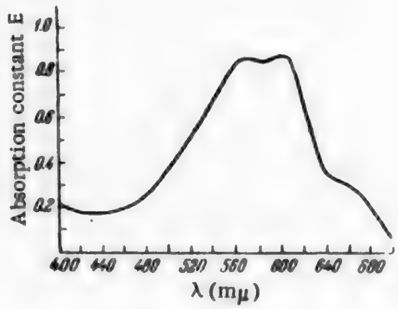


Fig. 4.

A comparison of the purity of the dyes, obtained with chromotropic acid (Curve a) and with its calcium salt (Curve b), is shown in Fig. 3 (cuvette 10 mm; 0.0035 and 0.0033% aqueous solutions, respectively).

6. 2-Naphthol-4-sulfonic Acid-(1-Azo-7)-1,8-dihydroxynaphthalene-3,6-disulfonic Acid, Trisodium Salt.

A suspension of 12.5 g (0.050 mole) of 1,2-diazohydroxynaphthalene-4-sulfonic acid, taken as 100% pure substance, in 60 ml of water was dissolved by the addition of soda to weakly alkaline reaction, and then added to a solution of the cyclic calcium salt of chromotropic acid, prepared as described in Section 1. After stirring for 4 hours 10 g of soda was added, and the resulting calcium carbonate precipitate was filtered and washed with 20 ml of water. The dye was isolated from the filtrate by the addition of 50 g of common salt and 25 ml of hydrochloric acid (d 1.14), filtered, and dried. The yield of 66% product was 35 g (72%). We were unable to obtain the dye by the usual synthesis techniques.

The dye shows a green color in alkaline medium, and a blue color in neutral and acid media. It dyes wool a blue color. When dyed in the usual manner, with after-chroming, it gives a gray-olive color, and in the presence of a large amount of sulfuric acid the colors become green. In both cases the color fastness is high.

The light-absorption curve for a solution of 7.2 g of the dye in 100 ml of water with a layer thickness of 10 mm is shown in Fig. 4.

7. 2,7 Bis-(4-nitro-2-hydroxybenzeneazo)-1,8-dihydroxynaphthalene-3,6-disulfonic Acid, Disodium Salt.

A stirred suspension of 16 g (0.104 mole) of 5-nitro-2-aminophenol in 20 ml of 10% hydrochloric acid was cooled to 3-5° and then diazotized with a solution of 7 g of sodium nitrite in 25 ml of water. The diazo solution was treated with soda to weakly alkaline reaction and then added to a solution of the cyclic salt of chromotropic acid, prepared the same as described above. After 4 hours the mixture was heated to 60°. Then 10 g of soda was added, and the calcium carbonate precipitate was filtered and washed with 20 ml of water. The bisazo compound was isolated from the filtrate by the addition of 50 g of common salt and 35 ml of hydrochloric acid (d 1.14), filtered, and dried. The yield of 72% product was 42 g (87.5%).

We were unable to obtain the bisazo compound by the usual synthesis techniques.

The light-absorption maximum for the aqueous solutions lies at $\lambda = 565$ mμ and for the monoazo compound at 527 mμ.

SUMMARY

1. In the usual method of synthesizing azo dyes from the sulfonic acids of 1,8-dihydroxynaphthalene, due to the oxidation of the latter in alkaline medium by diazo compounds and atmospheric oxygen, the yield of azo compounds is frequently small, and the obtained products are strongly contaminated. In general, the synthesis of azo compounds from diazo compounds of low activity and the synthesis of bisazo compounds cannot be achieved.

When the calcium and other salts of 1,8-dihydroxynaphthalene sulfonic acids, possessing strongly manifested intramolecular dissociation, are used in the synthesis, the secondary oxidation processes prove to be suppressed, which leads to an increase in the yields and purity of the synthesized compounds. Under these conditions the synthesis of bisazo compounds is easily accomplished, as is also the synthesis with weakly active diazo compounds.

2. We have described improved methods for the synthesis of these dyes: Acid Sky Blue S, Acid Chrome Blue K and Direct Sky Blue S, and also the synthesis of the new compounds: 4-methoxydiphenylamine-(4'-azo-7)-1,8-dihydroxynaphthalene-3,6-disulfonic acid; diphenylamine-2-sulfonic acid-(4-azo-7)-1,8-dihydroxynaphthalene-3,6-disulfonic acid; 2-naphthol-4-sulfonic acid-(1-azo-7)-1,8-dihydroxynaphthalene-3,6-disulfonic acid; and 2,7-bis-(4-nitro-2-hydroxybenzeneazo)-1,8-dihydroxynaphthalene-3,6-disulfonic acid.

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** In Russian.

COMPLEXES OF STANNIC CHLORIDE AND BROMIDE WITH THIOUREA

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The stannic halides form with various substances complexes of the types $SnX_4 \cdot A$, $SnX_4 \cdot 2A$, $SnX_4 \cdot 3A$ and $SnX_4 \cdot 4A$ or $SnX_4 \cdot 2A \cdot B$ and $SnX_4 \cdot 2A \cdot 2B$ [1]. The complexes $SnX_4 \cdot A$ are obtained with addenda that show a coordination capacity equal to two.* The compounds of this type represent dimers $[SnX_4 \cdot A]_2$. The complexes $SnX_4 \cdot 3A$ and $SnX_4 \cdot 4A$, in contrast to the compounds $SnCl_4 \cdot A$ and $SnX_4 \cdot 2A$, are electrolytes. The compound $SnCl_4 \cdot 3CH_3COOH$, can serve as an example, dissociating according to the scheme [3]:

$$SnCl_4 \cdot 3CH_3COOH \rightarrow [SnCl_4(CH_3COO)_2]H^- + CH_3COOH_2^+ \ .$$

Data on the spatial configuration of tin complexes are absent in the literature if the single paper by Ulich [4] on measuring the dipole moments of some tin compounds is neglected. Ulich came to the conclusion that the complexes studied by him have the cis-configuration.

In the present study we made an attempt to use thiourea as a means of obtaining some data on the structure of the complexes of tin halides.

EXPERIMENTAL

The following compounds were purified for the study. 1) Stannic chloride was prepared as indicated earlier [5]. To obtain the complexes we used the fraction boiling at 109° (690 mm); the substance was kept in sealed ampuls. 2) The thiourea was recrystallized from alcohol 8 times; m.p. 179° (literature: 179°). 3) The trichloroacetic acid was repeatedly distilled; the fraction boiling at 187° (699 mm) was taken: m.p. 57.8° (literature: 58°); the substance was kept in sealed ampuls. 4) The c.p. acetic acid was first subjected to fractional freezing, and then distilled; the fraction boiling at 113.5° (697.5 mm) was taken; m.p. 16.57° (literature: 16.6°).

Complex of stannic chloride with thiourea. Stannic chloride does not react directly with thiourea, since the thiourea is insoluble in stannic chloride. Thiourea is also almost insoluble in benzene, toluene, xylene, carbon tetrachloride and dichloroethane; consequently, we isolated the complex of stannic chloride with thiourea from glacial acetic acid.

Two solutions of stannic chloride and thiourea in acetic acid were mixed; the first solution in the ratio of 1 mole of stannic chloride per mole of thiourea; and the second solution in the ratio of 1 mole of stannic chloride per 2 moles of thiourea. In attempting to isolate the complex $SnCl_4 \cdot 4(NH_2)_2CS$ we used the mixed solvent $C_6H_6 + CCl_3COOH$, since thiourea is not sufficiently soluble in acetic acid. Proceeding from the following considerations, we attempted to obtain the compound $SnCl_4 \cdot 4(NH_2)_2CS$. If the thiourea adds in the cis-position, then due to the greater value of the trans-influence shown by thiourea molecules, a weakening of the bonds between the chlorine atoms lying opposite to the thiourea molecules and the central atom of the complexing agent, and replacement of the chlorine atoms by thiourea molecules, could be expected. In such case the compound with a 1:4 composition, i.e., $SnCl_4 \cdot 4(NH_2)_2CS$ should be formed. If the thiourea molecules are found in

* The solitary exception is the compound $SnCl_4 \cdot C_6H_5COOC_2H_5$ [2]. We are of the opinion that this case requires additional study.

the trans position, then in this case, even in the presence of excess thiourea molecules in the solution, the formation of the 1:2 compound should be expected.

The reaction of stannic chloride with thiourea is accompanied by a substantial heat effect, so to avoid strong self-heating the thiourea solution was added cautiously and with cooling to the stannic chloride solution. The precipitates depositing from the solutions when the stannic chloride and thiourea were mixed in the ratios 1:1 and 1:2 were separated from the mother liquors on porous glass filters, washed well with acetic acid, and then dried in a vacuum oven over P_2O_5. The precipitates, in both cases obtained as white nonhygroscopic powders, were analyzed for their tin and chlorine content.

We will present the analysis data for the precipitates that were obtained from the solutions in which the stannic chloride and thiourea were mixed in the ratio 1:2.

Found %: Sn 27.56, 29.27, 28.52; Cl 34.11, 34.27, 34.12. M 406 (in bromocamphor). $SnCl_4 \cdot 2(NH_2)_2CS$. Calculated %: Sn 28.76; Cl 34.36. M 412.77.

As a result, the analysis data show that the compound formed here corresponds to the formula $SnCl_4 \cdot 2(NH_2)_2CS$.

Analysis of the precipitates depositing from the solutions in which the stannic chloride and thiourea were mixed in equimolar amounts gave the following results.

Found %: Sn 28.46, 28.32; Cl 33.80, 34.19, 34.02. $SnCl_4 \cdot (NH_2)_2CS$. Calculated %: Sn 35.26; Cl 42.13.

From the analysis data it can be seen that the amount of tin and chlorine in the precipitate does not correspond to the 1:1 compound, but corresponds to the composition calculated for the 1:2 compound. As a result, we see that for the case where the stannic chloride and thiourea are mixed in equimolar amounts the complex $SnCl_4 \cdot 2(NH_2)_2CS$. is formed.

We will present the analysis data for the precipitate that was obtained from a mixed solution in which the stannic chloride and thiourea were present in the ratio 1:4.

Found %: Sn 27.02, 27.17; Cl 35.28, 35.43. $SnCl_4 \cdot 4(NH_2)_2CS$. Calculated %: Sn 21.01; Cl 25.10. Calculated %: Sn 28.76; Cl 34.36.

From the analysis results it can be seen that the amount of tin and chlorine in the precipitate is completely different from that calculated for the 1:4 compound, and instead agrees with the composition calculated for the 1:2 compound. We explain a lower value for the tin and a higher value for the chlorine against that calculated for the 1:2 compound as being due to the fact that we apparently failed to wash the precipitate completely free of CCl_3COOH. We did not make an attempt completely to free the precipitate of CCl_3COOH, since in our opinion even the results that we obtained are convincing proof that it is the 1:2 complex, and not the 1:4, that deposited in the precipitate.

To support the analysis results obtained for the precipitates we ran a cryoscopic titration [6] on thiourea with stannic chloride in CCl_3COOH and CH_3COOH. The addition of the first drop of stannic chloride to the solution of thiourea in either CCl_3COOH or CH_3COOH resulted in the immediate precipitation of the complex, since the formed compound is difficultly soluble in CCl_3COOH and CH_3COOH. The deposition of a precipitate was observed up to the equivalent point. The depression-composition (in mole %) diagram is shown in Fig. 1; Curve I relates to the titration of thiourea with stannic chloride in CCl_3COOH, and Curve II to the titration run in CH_3COOH. From the diagram it can be seen that in measure with the addition of stannic chloride to the thiourea solution there is in both cases (Curves I and II) a drop in the depression clear up to 33-34 mole % $SnCl_4$ caused by the removal of dissolved thiourea molecules into the precipitate; further addition of stannic chloride causes a rise in the depression. The singular point on the diagram is found at the composition corresponding to the compound $SnCl_4 \cdot 2(NH_2)_2CS$.

As a result, both the analysis data and the crysoscopic titration results show that when stannic chloride and thiourea are mixed in various stoichiometric proportions only the one compound $SnCl_4 \cdot 2(NH_2)_2CS$ is formed. This complex does not melt, but it does sublime with partial decomposition at 94°. It is poorly soluble in benzene, toluene, nitrobenzene and phenol; it is substantially more soluble in acetic and trichloroacetic acids.

Complex of stannic bromide with thiourea. The complex from stannic bromide and thiourea was also obtained from solutions in glacial acetic acid or in the mixed solvent $CCl_3COOH + C_6H_6$. The weighed samples of stannic bromide and thiourea, taken on the basis of 1 mole of stannic bromide per mole of thiourea, 1 mole

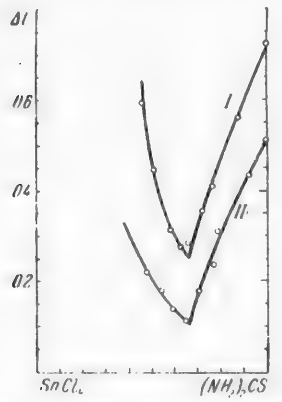

Fig. 1. Depression-composition diagram of the system $SnCl_4$–$(NH_2)_2CS$. (Explanation in text).

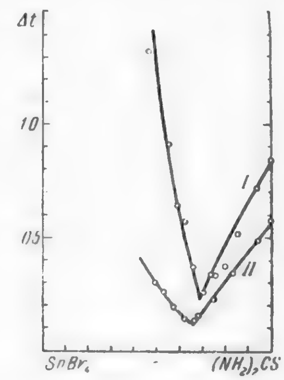

Fig. 2. Depression-composition diagram of the system $SnBr_4$ – $(NH_2)_2CS$. (Explanation in text).

of stannic bromide per 2 moles of thiourea, and 1 mole of stannic bromide per 4 moles of thiourea, were dissolved separately in the solvent, and the solutions were mixed. The deposition of precipitates and the evolution of heat were observed when the stannic bromide solutions were mixed with the thiourea solutions. The precipitates were separated from the mother liquors, correspondingly washed with either acetic acid or benzene, and dried in a vacuum-oven over P_2O_5.

Analysis of the precipitate obtained from the solutions in which the stannic bromide and thiourea were mixed in a 2:1 ratio gave the following results.

Found %: Sn 18.75, 19.44, 19.84; Br 54.17, 54.13, 54.15. $SnBr_4 \cdot 2(NH_2)_2CS$. Calculated %: Sn 20.10; Br 54.13.

From the analysis data it can be seen that the obtained precipitate is the complex $SnBr_4 \cdot 2(NH_2)_2CS$.

We also present the analysis data for the precipitate that was obtained when stannic bromide and thiourea were mixed in acetic acid solution in the ratio 1:1.

Found %: Sn 19.85, 19.78, 18.75. M 609 (in bromocamphor). $SnBr_4 \cdot (NH_2)_2CS$. Calculated %: Sn 23.07. M 514.50. $SnBr_4 \cdot 2(NH_2)_2CS$. Calculated %: Sn 20.10. M 590.62.

We also present the analysis results obtained for the precipitate that deposited from the mixed solvent in which the stannic bromide and thiourea were present in a 1:4 ratio.

Found %: Sn 19.83, 19.73, 19.58; Br 53.89, 54.32, 53.49. $SnBr_4 \cdot 4(NH_2)_2CS$. Calculated %: Sn 15.98; Br 43. 3. $SnBr_4 \cdot 2(NH_2)_2CS$. Calculated %: Sn 20.10; Br 54.13.

The analysis data show that the amount of tin and bromine in the precipitate is completely different from that calculated for the complex $SnBr_4 \cdot 4(NH_2)_2CS$, and shows good agreement with that calculated for the complex $SnBr_4 \cdot 2(NH_2)_2CS$. As a result, we see that even in the presence of a large excess of thiourea again only the one complex, $SnBr_4 \cdot 2(NH_2)_2CS$, is formed.

The results for the cryoscopic titration of thiourea with stannic bromide, run in CCl_3COOH and CH_3COOH, are plotted in Fig. 2. Curve I relates to the measurements made in CCl_3COOH, and Curve II to those made in CH_3COOH. Examination of the plots reveals that in measure with adding stannic bromide to solutions of thiourea in CCl_3COOH and CH_3COOH, the depression drops as the result of the precipitation reaction, and then rises. The singular point on the diagram is found at the composition corresponding to the complex $SnBr_4 \cdot 2(NH_2)_2CS$. These data support the analysis results.

The complex $SnBr_4 \cdot 2(NH_2)_2CS$ is difficultly soluble in benzene, toluene, nitrobenzene and phenol, and more readily soluble in acetic and trichloroacetic acids; it sublimes at 80°, but does not melt.

The discussed research data suggest that in the complexes obtained by us the thiourea molecules are found in the trans position.

The authors wish to thank M. I. Usanovich for his valuable advice and constant interest in the work.

SUMMARY

1. The complexes of stannic chloride and bromide with thiourea, namely $SnCl_4 \cdot 2(NH_2)_2CS$ and $SnBr_4 \cdot 2(NH_2)_2CS$. were prepared.

2. It was shown that stannic chloride and bromide do not form the $SnX_4 \cdot (NH_2)_2CS$ or $SnX_4 \cdot 4(NH_2)_2CS$ types of complexes with thiourea.

3. The theory was expressed that the obtained complexes have a trans configuration.

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COMPLEXES OF STANNIC CHLORIDE AND BROMIDE WITH GLYCINE

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We had established [1] that $SnCl_4$ and $SnBr_4$ react with thiourea to form the complexes $SnCl_4 \cdot 2(NH_2)_2CS$ and $SnBr_4 \cdot 2(NH_2)_2CS$. On the basis of these data we expressed the theory that thiourea, in its formation of complexes with $SnCl_4$ and $SnBr_4$, is found in the trans position. Desiring to obtain additional data on the structure of tin complexes, we decided to study the reaction of $SnCl_4$ and $SnBr_4$ with glycine.

EXPERIMENTAL

Complexes of $SnCl_4$ with glycine. The c.p. glycine was not purified further, while the other compounds were prepared as described earlier [1]. The complexes from stannic chloride and glycine were isolated from the solutions of the reactants in CH_3COOH and in CCl_3COOH. To obtain the complexes, the weighed samples of stannic chloride and glycine (taken on the basis of 1 mole of stannic chloride for 1 mole, 2 moles and 4 moles of glycine, respectively) were dissolved separately in CH_3COOH, and the obtained solutions were poured together. The experiment in which the stannic chloride and glycine were mixed in a ratio of 1:4 was run in the hopes that we would obtain the complex $SnCl_4 \cdot 4NH_2CH_2COOH$. The formation of the 1:4 complex could be postulated, proceeding from the known amphoteric properties of glycine and taking into consideration the fact that the addition of glycine to stannic chloride should lead to enhanced acidic properties for the glycine. In addition, analogous compounds of stannic chloride with alanine [2] and with ammonia [3] are described in the literature.

Considerable heat-evolution is observed when the solutions of stannic chloride and glycine are mixed. A precipitate deposited from the mixture with a 1:1 ratio, which after thorough washing and drying was obtained as a colorless, extremely hygroscopic powder. A precipitate failed to deposit from the mixture with a reactant ratio of 1:2, since apparently crystallization was prevented here by the extremely high viscosity shown by a mixture of this composition. Analysis of the precipitate for its tin and chlorine content gave the following results.

Found %: Sn 22.23, 21.68; Cl 27.23, 26.98. $SnCl_4 \cdot NH_2CH_2COOH$. Calculated %: Sn 35.37; Cl 42.26. $SnCl_4 \cdot 2NH_2CH_2COOH$. Calculated %: Sn 28.90, Cl 34.54.

The amount of tin and chlorine found in the precipitate fails to agree with that calculated for either the complex $SnCl_4 \cdot NH_2CH_2COOH$ or the complex $SnCl_4 \cdot 2NH_2CH_2COOH$. We postulated that the obtained precipitate is the complex $SnCl_4 \cdot 2NH_2CH_2COOH \cdot 2CH_3COOH$. From the analysis data it can be seen that the amount of tin and chlorine in the precipitate actually corresponds to that calculated for the complex $SnCl_4 \cdot 2NH_2CH_2COOH \cdot 2CH_3COOH$ (22.36% Sn and 26.72% Cl). The formation of a complex of this composition is entirely probable, since the medium from which the complex was obtained is acetic acid, which could have added in the outer sphere of the complex. Similar mixed complexes of stannic chloride have been obtained with carboxylic acids [4, 5].

We will present the results of determining the molecular weight of the precipitate in acetic acid.

0.2460 g of substance; 29.84 g CH_3COOH; Δt 0.172°. Found: M 187. $SnCl_4 \cdot 2NH_2CH_2COOH \cdot 2CH_3COOH$. Calculated: M 530.77.

From the molecular weight determination data it can be seen that the found molecular weight is equal to

$\sim ^1/_3$ the formula weight, i.e., the complex dissociates into three ions. We depict the dissociation scheme as follows:

$$SnCl_4 \cdot 2NH_2CH_2COOH \cdot 2CH_3COOH \rightleftharpoons [SnCl_4(NH_2CH_2COO)_2]^{--} + 2CH_3COOH_2^+$$

The complex $SnCl_4 \cdot 2NH_2CH_2COOH \cdot 2CH_3COOH_2^+$ melts at 74.6° and in the molten state is a clear, colorless, extremely viscous liquid.

The solutions in which the stannic chloride and glycine were mixed in a ratio of 1:4 showed stratification on standing. We separated the heavy lower layer, washed it with acetic acid, and then removed the latter by heating to 150°. After removing the acetic acid we obtained a viscous liquid, bottle green in color and capable of being stretched into thin threads; when cooled to room temperature this liquid congealed into a glassy mass.

Analysis of the viscous liquid gave the following results.

Found %: Sn 20.21, 20.26, 20.27; Cl 23.92, 23.72. $SnCl_4 \cdot 4NH_2CH_2COOH$. Calculated %: Sn 21.17; Cl 25.29.

The analysis data show that the obtained substance is the $SnCl \cdot 4NH_2CH_2COOH$. Low analysis results were obtained, apparently for the reason that we were unable completely to remove the acetic acid. The complex $SnCl_4 \cdot 4NH_2CH_2COOH$ was also obtained by replacing two molecules of CH_3COOH from the outer sphere of the complex $SnCl_4 \cdot 2NH_2CH_2COOH \cdot 2CH_3COOH$ by glycine, the latter functioning as a stronger base. When the molten complex $SnCl_4 \cdot 2NH_2CH_2COOH \cdot 2CH_3COOH$ was treated with glycine a quite volatile liquid condensed on the cover of the box. The characteristic sharp odor and refractive index of this liquid served as evidence that the evolved liquid is acetic acid ($n^{18.9}$ 1.3759, while from the literature: $n^{22.9}$ 1.37152).

The reaction proceeds in accord with the equation:

$$[SnCl_4(NH_2CH_2COO)_2]^{--}(CH_3COOH_2)_2^+ + 2NH_2CH_2COOH \rightleftharpoons$$
$$\rightleftharpoons [SnCl_4(NH_2CH_2COO)_2]^{--}(NH_2CH_2COOH_2)_2^+ + 2CH_3COOH.$$

The complex $SnCl_4 \cdot 4NH_2CH_2COOH$ obtained in this manner represents the already-described viscous liquid.

Found %: Sn 19.46, 19.10, 19.49. $SnCl_4 \cdot 4NH_2CH_2COOH$. Calculated %: Sn 21.17.

The found content of tin in the viscous liquid is also lower than that calculated for the 1:4 complex, since in this case also we were unable completely to remove the acetic acid from the extremely viscous liquid. The cryoscopic determination of the molecular weight in acetic acid solution gave the following results.

Found: M 208. $SnCl_4 \cdot 4NH_2CH_2COOH$. Calculated: M 560.81.

The found molecular weight constitutes a value that is close to $^1/_3$ of the formula molecular weight; this shows that the complex dissociates into three ions. In our opinion, the dissociation proceeds by the equation:

$$SnCl_4 \cdot 4NH_2CH_2COOH \rightleftharpoons [SnCl_4(NH_2CH_2COO)_2]^{--} + 2NH_2CH_2COOH_2^+.$$

As a result, from the analysis data and the cryoscopic determination of the molecular weight we come to the conclusion that stannic chloride forms with glycine the complex $SnCl_4 \cdot 4NH_2CH_2COOH$.

When we attempted to obtain the complex $SnCl_4 \cdot 2NH_2CH_2COOH$ in CH_3COOH, we isolated the mixed complex:

$$SnCl_4 \cdot 2NH_2CH_2COOH \cdot 2CH_3COOH,$$

since CH_3COOH, being a base with respect to

$$SnCl_4 \cdot 2NH_2CH_2COOH,$$

added in the outer sphere. However, taking into consideration the fact that the formation of the complexes $SnCl_4 \cdot 2NH_2CH_2COOH \cdot 2CH_3COOH$ and $SnCl_4 \cdot 4NH_2CH_2COOH$ precedes the formation of the complex $SnCl_4 \cdot 2NH_2CH_2COOH$, we decided to obtain the complex $SnCl_4 \cdot 2NH_2CH_2COOH$ from a different solvent. We settled on the choice of CCl_3COOH as the solvent for the following reasons. It is known that CCl_3COOH does not react with $SnCl_4$ [6] and the strong hydrogen acids $HClO_4$ [7] and H_2SO_4 [8]. Since $SnCl_4 \cdot 2NH_2CH_2COOH$ can in no way be a stronger acid than $HClO_4$, then CCl_3COOH should not add in the outer sphere. Consequently, in CCl_3COOH we should obtain the compound $SnCl_4 \cdot 2NH_2CH_2COOH$. On the other hand, it was necessary to expect the formation of the complex of CCl_3COOH with glycine. We failed to find any indications in the literature on the existence of such a compound, and consequently we subjected this postulation to experimental verification. For this purpose we ran the cryoscopic titration of glycine with trichloroacetic acid in CH_3COOH. The titration curve (Fig. 1) is composed of two branches, intersecting in the point that corresponds to the complex with an equimolar composition. The depression at the equivalent point is twice the depression shown by the original solution. Such an increase in the depression shows that the complex $CCl_3COOH \cdot NH_2CH_2COOH$ dissociates into two ions. The dissociation proceeds by the equation:

$$CCl_3COOH + NH_2CH_2COOH \rightleftharpoons NH_2CH_2COOH_2^+ + CCl_3COO^-.$$

Measurement of the conductance of the system $CCl_3COOH - NH_2CH_2COOH$ in acetic acid confirmed the electrolytic dissociation of this complex. The diagram for the conductance of this system is shown in Fig. 2. From the figure it can be seen that in measure with adding CCl_3COOH to the glycine solution in CH_3COOH the conductance increases, passes through a maximum, and then drops. The presence of conductance for the solution of glycine in CH_3COOH shows that CH_3COOH also reacts with glycine with the formation of a complex that is capable of conducting a current. When equimolar amounts of glycine and molten CCl_3COOH are mixed, a crystalline compound is formed, which is soluble in excess CCl_3COOH.

As a result, we elucidated that CCl_3COOH reacts with glycine to form the complex $NH_2CH_2COOH_2H_2^+ \cdot CCl_3COO^-$. However, taking into consideration the acid-base properties of $SnCl_4 \cdot NH_2CH_2COOH$ and CCl_3COOH, we undertook to isolate the complex $SnCl_4 \cdot 2NH_2CH_2COOH$ by mixing stannic chloride with glycine in CCl_3COOH.

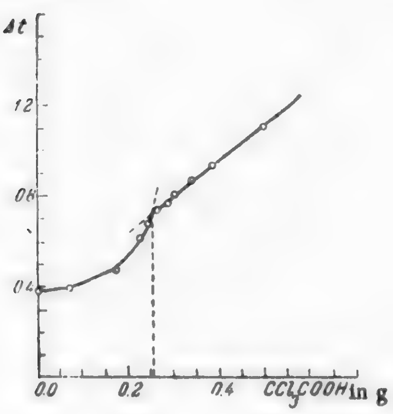

Fig. 1. Cryoscopic titration of glycine (0.1175 g) with trichloroacetic acid.

In connection with this we ran the cryoscopic titration of glycine with stannic chloride in CCl_3COOH. The deposition of a precipitate and a corresponding drop in the depression was observed when stannic chloride was added to a solution of glycine in CCl_3COOH. The depression-composition diagram (Fig. 3) is represented by two curves, intersecting in the singular point corresponding to the minimum depression. The position of the singular point is found at 33 mole % $SnCl_4$, i.e., at the composition of the complex

$$SnCl_4 \cdot 2NH_2CH_2COOH.$$

Using the cryoscopic titration data as a guide, we isolated this complex from CCl_3COOH. The obtained precipitate was filtered on a porous glass filter, thoroughly washed from CCl_3COOH with benzene, and then dried in a vacuum-oven over P_2O_5. Analysis of the precipitate for its tin and chlorine content gave the following results.

Found %: Sn 28.18, 27.40; Cl 32.92, 31.79, 33.05. $SnCl_4 \cdot 2NH_2CH_2COOH$. Calculated %: Sn 28.90; Cl 34.54.

From the analysis data it can be seen that the obtained precipitate is the complex $SnCl_4 \cdot 2NH_2CH_2COOH$.

The complex $SnCl_4 \cdot 2NH_2CH_2COOH$ represents extremely hygroscopic white crystals, which on exposure to the air easily absorb moisture and deliquesce; this apparently explains the lower content of tin and chlorine in the precipitate against that calculated for the 1:2 complex.

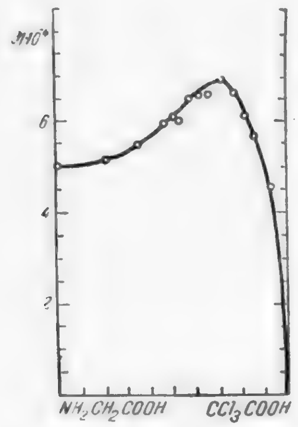

Fig. 2. Conductance of the system $NH_2CH_2COOH - CCl_3COOH$ (Composition in mole %).

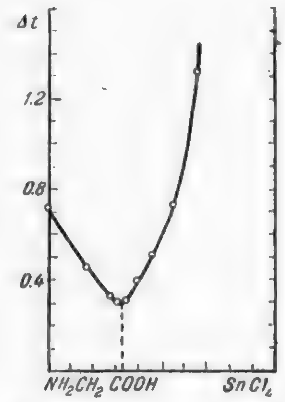

Fig. 3. Cryoscopic titration of glycine with stannic chloride (Composition in mole %).

To the complex $SnCl_4 \cdot 2NH_2CH_2COOH$ we added directly, in the outer sphere, two molecules of CH_3COOH and obtained a viscous transparent liquid, which after long standing crystallized completely in the form of colorless, transparent crystals. The analysis data for the tin and chlorine content of these crystals are given below.

Found %: Sn 22.07; Cl 26.85, 26.79, 26.67. $SnCl_4 \cdot 2NH_2CH_2COOH \cdot 2CH_3COOH$. Calculated %: Sn 22.36, Cl 26.72.

As a result, these analysis data also support the existence of the complex $SnCl_4 \cdot 2NH_2CH_2COOH \cdot 2CH_3COOH$.

We displaced the acetic acid from the outer sphere of the complex $SnCl_4 \cdot 2NH_2CH_2COOH \cdot 2CH_3COOH$ by glycine and again obtained a viscous liquid with a bottle-green color. Analysis of this viscous liquid revealed that its tin and chlorine content corresponds to the complex $SnCl_4 \cdot 4NH_2CH_2COOH$.

We also attempted to obtain the complex of tin with 6 moles of glycine in CH_3COOH; however, here it proved that the excess glycine crystallizes from solution, while the complex $SnCl_4 \cdot 4NH_2CH_2COOH$ remains in solution.

Complexes of stannic bromide with glycine. The complexes of stannic bromide with glycine were obtained in glacial CH_3COOH. Mixtures of stannic bromide with glycine were prepared in the ratios of 1 mole of stannic bromide for 1 and 2 moles of glycine. A precipitate deposited from the mixture with a 1:1 ratio, which was separated from the mother liquor, washed with CH_3COOH, dried over P_2O_5, and then analyzed. The mixture with a 1:2 ratio of the reactants was an extremely viscous liquid, from which we were unable to crystallize a complex. The analysis of the precipitate, obtained from the 1:1 mixture, is given below.

Found %: Sn 16.24, 16.37, 15.71, 16.22; Br 44.95, 45.97, 45.88. $SnBr_4 \cdot NH_2CH_2COOH$. Calculated %: Sn 23.12; Br 62.26. $SnBr_4 \cdot 2NH_2CH_2COOH$. Calculated %: Sn 20.17; Br 54.32.

From the analysis data it can be seen that the amount of tin and chlorine in the precipitate is different from that calculated for either the 1:1 complex or the 1:2 complex, but that it agrees well with the formula of the complex

$$SnBr_4 \cdot 2NH_2CH_2COOH \cdot 2CH_3COOH,$$

which contains 16.75% of Sn and 45.11% of Br.

The determination of the molecular weight of the precipitate by the cryoscopic method gave the following result:

0.3111 g of substance; 16.60 g CH_3COOH; Δt 0.305°. Found M 240. $SnBr_4 \cdot 2NH_2CH_2COOH \cdot 2CH_3COOH$. Calculated: M 708.62.

From the obtained data it can be seen that the found molecular weight is equal to $\frac{1}{3}$ the molecular weight of the complex $SnBr_4 \cdot 2NH_2CH_2COOH \cdot 2CH_3COOH$. Consequently, the given complex decomposes into three ions, which is in complete accord with our representations relative to the structure of complexes of this type.

The complex $SnBr_4 \cdot 2NH_2CH_2COOH \cdot 2CH_3COOH$ represents a hygroscopic substance with m.p. 70°, which is difficultly soluble in organic solvents.

The complex $SnBr_4 \cdot 4NH_2CH_2COOH$ was obtained by two methods – by mixing stannic bromide with glycine in the ratio 1:4 in CCl_3COOH, and by displacing CH_3COOH from the outer sphere of the complex $SnBr_4 \cdot 2NH_2CH_2COOH \cdot 2CH_3COOH$ by glycine. When the molten complex $SnBr_4 \cdot 2NH_2CH_2COOH \cdot 2CH_3COOH$ was treated with glycine we observed the liberation of a liquid, which condensed as drops on the cover of the container. The sharp odor and refractive index ($n^{10.3}$ 1.3788) testified to the fact that this liquid is CH_3COOH.

The complex $SnBr_4 \cdot 4NH_2CH_2COOH$ represents a viscous liquid, capable of being stretched at 80-100° into long slender threads. Analysis of the viscous liquid gave the following results.

Found %: Sn 14.05*, 15.76, 15.73, 15.47; Br 42.89, 43.98. $SnBr_4 \cdot 4NH_2CH_2COOH$. Calculated %: Sn 16.07; Br 43.28.

The analysis results show that the viscous liquid is the complex $SnBr_4 \cdot 4NH_2CH_2COOH$.

The results of determining the molecular weight of this substance are given below.

Found: M 225. $SnBr_4 \cdot 4NH_2CH_2COOH$. Calculated: M 738.66.

The found molecular weight is equal to ≈ $\frac{1}{3}$ the formula molecular weight of the complex $SnBr_4 \cdot 4NH_2CH_2COOH$. On the basis of the analysis data and the cryoscopic measurements we come to the conclusion that the complex $SnBr_4 \cdot 4NH_2CH_2COOH$ exists.

DISCUSSION OF RESULTS

As a result, we established that stannic chloride and bromide form with glycine the complexes $SnCl_4 \cdot 2NH_2CH_2COOH$, $SnCl_4 \cdot 2NH_2CH_2COOH \cdot 2CH_3COOH$, $SnCl_4 \cdot 4NH_2CH_2COOH$, $SnBr_4 \cdot 2NH_2CH_2COOH \cdot COOH.$ $2CH_3COOH$ and $SnBr_4 \cdot 4NH_2CH_2\ COOH$. An attempt to prepare the complexes $SnX_4 \cdot NH_2CH_2COOH$ and $SnX_4 \cdot 6NH_2CH_2COOH$ gave negative results; apparently, these complexes do not exist. The complex $SnBr_4 \cdot 2NH_2CH_2COOH$ undoubtedly exists; however, we were unable to isolate it in pure form.

The complexes $SnX_4 \cdot 2NH_2CH_2COOH$ are quite strong acids which add in the outer sphere either CH_3COOH or NH_2CH_2COOH, forming complexes of salt-like character.

The reactions proceed by the equations:

$$1)\ SnX_4 \cdot 2NH_2CH_2COOH + 2CH_3COOH \rightleftharpoons [SnX_4(NH_2CH_2COO)_2]^{--} + \\ + 2CH_3COOH_2^+,$$

$$2)\ SnX_4 \cdot 2NH_2CH_2COOH + 2NH_2CH_2COOH \rightleftharpoons [SnX_4(NH_2CH_2COO)_2]^{--} + \\ + 2NH_2CH_2COOH_2^+.$$

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* Displacement of CH_3COOH by glycine.

Measurement of the molecular weights of these complexes revealed that the apparent molecular weight is equal to $\frac{1}{3}$ the formula molecular weight. These data support our representations relative to the structures of the complexes $SnX_4 \cdot 2NH_2CH_2COOH \cdot 2CH_3COOH$ and $SnX_4 \cdot 4NH_2CH_2COOH$.

It could be postulated that the reaction of stannic chloride and bromide with glycine leads to the formation of products in which either $[SnX_2 \cdot 4NH_2CH_2COOH]^{++}2X^-$ or $[SnX_2 \cdot 2NH_2CH_2COOH \cdot 2CH_3COOH]^{++}2X^-$ is implanted. In this case also the molecular weights would be equal to $\frac{1}{3}$ of the formula molecular weights. However, in our opinion, this postulation is rejected for the following reasons. The extensive literature on the complexes of tetravalent tin shows that tin halides are incapable of implantation reactions. The possibility of implantation is postulated by S. P. Miskidzhyan [9], and by G. N. Volnov and E. G. Kuzmina [10]. In the presence of the implantation reaction the formation of complexes of the type $SnX_4 \cdot 6A$ could be expected; however, compounds of such composition are not described in the literature, and our data show that the complex $SnCl_4 \cdot 6NH_2CH_2COOH$ does not exist. In addition, if the possibility of implantation reactions for tin halides is assumed, then the question arises why, for example, doesn't thiourea [1] form implantation products with tin halides?

These considerations cause us to believe that the electrolytic dissociation scheme presented above, and proposed by M. I. Usanovich in examining the structures of the complexes $SnCl_4 \cdot 3CH_3COOH$ and $SnCl_4 \cdot 3HCOOH$, is correct.

The absence of implantation products suggests that the addenda in the formation of complexes with the halides of tetravalent tin are found in the trans position.

SUMMARY

1. The following complexes were prepared, $SnCl_4 \cdot 2NH_2CH_2COOH$, $SnCl_4 \cdot 2NH_2CH_2COOH \cdot 2CH_3COOH$, $SnCl_4 \cdot 4NH_2CH_2COOH$, $SnBr_4 \cdot 2NH_2CH_2COOH \cdot 2CH_3COOH$ and $SnBr_4 \cdot 4NH_2CH_2COOH$.

2. It was established that the molecular weights of these complexes, with the exception of $SnCl_4 \cdot 2NH_2CH_2COOH$, are equal to $\frac{1}{3}$ of the formula molecular weights. These data support our representations relative to the structure of complexes of the type $SnX_4 \cdot 3A$ and $SnX_4 \cdot 4A$.

3. It was shown that the complexes $SnX_4 \cdot NH_2CH_2COOH$ and $SnX_4 \cdot 6NH_2CH_2COOH$ do not exist.

4. Data were obtained thatspeak in favor of the transconfiguration for the complexes of tetravalent tin.

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CONTACT TRANSFORMATIONS OF DICYCLOHEPTYL IN THE PRESENCE OF PLATINIZED CARBON

S. I. Khromov, I. M. Kuznetsova and E. S. Balenkova

In previous studies [1] on the catalytic transformation of alkyl- and arylcycloheptanes under the conditions of dehydrogenation catalysis we established that the catalysis proceeds with isomerization of a seven-membered ring into a six-membered, and with the formation of considerable amounts of gem-substituted cyclohexane hydrocarbons. Thus, methylcycloheptane in contact with platinized carbon at 320° gives up to 17% of gem-dimethylcyclohexane and a mixture of aromatic hydrocarbons (toluene, m-, p- and o-xylenes).

In a similar manner the catalysis under the above described conditions of ethyl-, propyl- and butylcycloheptanes leads to the formation of gem-methylalkylcyclohexanes (up to 29%) and a complex mixture of aromatic hydrocarbons.

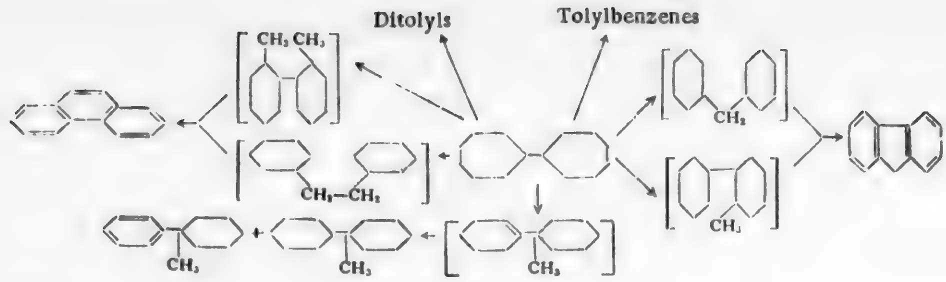
Under the conditions of dehydrogenation catalysis, the arylcycloheptanes (phenylcycloheptane and α-naphthylcycloheptane) suffer profound aromatization with the formation of multinuclear aromatic hydrocarbons (fluorene, fluoranthene, isochrysofluorene), while the amount of the corresponding gem-methylarylcyclohexane in the catalyzate is reduced to 5-7%.

It seemed of interest to study the phenomenon noted by us for the contact isomerization of cycloheptane hydrocarbons into dicycloheptyl – a hydrocarbon containing two seven-membered rings. For this purpose we synthesized dicycloheptyl, which was contacted at 320° with 10% platinized carbon. The catalyzate was subjected to freezing to isolate the crystalline hydrocarbons formed in the catalysis, while the catalyzate portion remaining liquid after freezing was subjected to separation into a naphthenic and aromatic portion by the method of chromatographic adsorption on silica gel.

The naphthenic portion of the catalyzate was shown to contain 1-methyl-1-cyclohexylcyclohexane, the formation of which could be explained by the fact that several processes show simultaneous progress during the catalysis: 1) the isomerization of both of the seven-membered rings of the starting hydrocarbon into six-membered rings, in which connection at least one of the two methyl groups formed in this case is found in the gem-position; 2) the cleavage of one of the methyl radicals, formed in the contraction of seven-membered rings into six-membered; and 3) the formation of an intermediate reaction product of 1-methyl-1-cyclohexenylcyclohexane, which as the result of "irreversible catalysis", according to N. D. Zelinsky, is transformed into 1-methyl-1-cyclohexylcyclohexane and 1-methyl-1-phenylcyclohexane.

A study of the composition of the aromatic portion of the catalyzate reveals the profound aromatization suffered by the starting dicycloheptyl under the catalysis conditions. Thus, in the aromatic portion of the catalyzate we found phenanthrene, fluorene, 1-methyl-1-phenylcyclohexane, tolylbenzenes and the ditolyls.

The contact transformations of dicycloheptyl can be depicted by the following scheme:



The formation of phenanthrene from dicycloheptyl apparently proceeds through the intermediate stage of either diphenylethane or o, o'-ditolyl, which under the catalysis conditions suffer dehydrocyclization into phenanthrene. The formation of phenanthrene as one of the main reaction products of the catalytic transformation of dicycloheptyl on platinized carbon is found in accord with the investigations of N. D. Zelinsky and N. V. Elagina, who studied the transformations of cyclohexylcycloheptylmethane under experimental conditions similar to ours, and also obtained phenanthrene as the main reaction product [2]. The presence of fluorene in the catalyzate can be explained by the fact that the starting hydrocarbon, suffering both catalytic isomerization and dehydrogenation, forms either diphenylmethane or o-tolylbenzene as an intermediate product, which are subsequently transformed into fluorene [3].

EXPERIMENTAL

Synthesis of Hydrocarbons

1. Dicycloheptyl. Using the method of Mossettig and Burger [4], we synthesized suberone by treating cyclohexanone with diazomethane. Reduction of the ketone over Raney nickel in an oscillating autoclave at room temperature and a hydrogen pressure of 70 atm gave suberol. A total of 446 g of suberol was prepared (in yields up to 95%), b.p. 76 - 77° (12 mm), d_4^{20} 0.9532, n_D^{20} 1.4757.

Literature for suberol: b.p. 90° (28 mm), n_D^{20} 1.4753 [5].

The obtained suberol, first in the cold, and then at the temperature of the boiling water bath, was saturated with hydrogen bromide gas. To remove traces of unreacted suberol the reaction mixture was treated with concentrated sulfuric acid, washed, dried, and fractionated in vacuo. A total of 382 g (70%) of suberyl bromide was obtained.

B.p. 85° (20 mm), d_4^{20} 1.3076, n_D^{20} 1.5057, MR_D 40.11; calc. 40.09. Literature for suberyl bromide: B. p. 101.5° (40 mm), d_4^{20} 1.299 [6].

The Grignard method (A) and the Wurtz method (B) were used to synthesize dicycloheptyl.

A. The reaction of suberone with suberylmagnesium bromide gave 1-cycloheptyl-1-cycloheptanol. The synthesized alcohol was dehydrated in the presence of formic acid, and the 1-cycloheptyl-1-cycloheptene obtained here was hydrogenated over platinized carbon at room temperature. The yield of dicycloheptyl was 11.6 g (8.5%).

B. To a mixture of 120 g (0.67 mole) of suberyl bromide and 450 ml of absolute ether was added 46 g (2 moles) of metallic sodium in the form of wire.

The reaction mixture was let stand at room temperature for 5 days, after which the mixture was heated to ether boil for 7 hours.

Decomposition of the sodium with water and removal of the ether by distillation gave 29.3 g (45%) of dicycloheptyl.

The disuberyl synthesized by the two methods was purified further by its chromatographic adsorption on silica gel, and then it was distilled through a column under reduced pressure. The total yield of dicycloheptyl was 63 g.

B.p. 121.0 - 121.5° (5mm), d_4^{20} 0.9069, n_D^{20} 1.4927. MR_D 62.21; calc. 62.45. Literature for suberyl bromide: b.p. 291 - 292° (728 mm); d_4^{20} 0.9069. Found %: C 87.47, 87.46; H 13.50, 13.49. $C_{14}H_{26}$. Calculated %: C 86.52; H 13.48.

2. Synthesis of 1-Methyl-1-cyclohexylcyclohexane. The reaction of 1-methyl-1-cyclohexanol with benzene in the presence of aluminum chloride [8] gave 1-methyl-1-phenylcyclohexane; the passing of the latter at 180° over platinized carbon in a hydrogen stream gave 1-methyl-1-cyclohexylcyclohexane, which after purification by chromatographic adsorption on silica gel and fractional distillation in vacuo through a column had:

B. p. 104.5 - 105.0° (9 mm), d_4^{20} 0.8897, n_D^{20} 1.4824. MR_D 57.83; calc. 58.01. Found %: C 86.52; H 13.48. 1-Methyl-1-cyclohexylcyclohexane is new in the literature.

Contact Transformations of Dicycloheptyl

Through a catalyst tube containing 60 ml of 10% platinized carbon at 320° was passed 50 g of dicycloheptyl at a space velocity of 0.2. Two passes gave 40 g of catalyzate and 34.6 liters of gas. An apparatus designed by the All-Union Heat Engineering Institute was used to analyze the gaseous products. The gas analysis results were: H_2 91.4%; CH_4 8.6%.

Study of the Catalyzate. The catalyzate, a liquid showing slight fluorescence and containing some colorless crystals as impurity, congealed to a hard glassy mass when cooled to −55°. To isolate the solid hydrocarbons formed in the catalysis 39.9 g of the catalyzate was mixed with isopentane, and the mixture was cooled to −20°. The obtained crystals (10.9 g) were filtered and subjected to fractional crystallization from aqueous ethyl alcohol.

As the result of repeated crystallization the solid portion of the catalyzate gave the following:

1) Phenanthrene (8.5 g) with m.p. 98°. Its mixed m.p. with pure phenanthrene failed to be depressed.

2) Fluorene (1.2 g) with m.p. 113°. Its mixed melting point with pure fluorene was not depressed.

The portion of the catalyzate that remained liquid (19.5 g) after the freezing was separated into a naphthenic and an aromatic portion by chromatographic adsorption on silica gel.

The naphthenic portion isolated as the result of chromatographic adsorption (0.97 g), had:

B. p. 104 - 105° (8 mm), d_4^{20} 0.8895, n_D^{20} 1.4810. Found %: C 86.51, 86.47; H 13.53, 13.49. $C_{13}H_{24}$. Calculated %: C 86.52; H 13.48.

A comparison of the constants of the obtained catalyzate fraction and of the elementary analysis results with the constants of the 1-methyl-1-cyclohexylcyclohexane specially synthesized by us permits considering the isolated fraction as being mainly 1-methyl-1-cyclohexylcyclohexane.

Then by chromatographing we isolated the first fraction of the aromatic portion of the catalyzate (possessing a lower index of refraction then the subsequent fractions), from which by fractional distillation we isolated a hydrocarbon (2.47 g) with the constants: b.p. 95 - 97° (8mm), d_4^{20} 0.9390, n_D^{20} 1.5235.

When the constants of this catalyzate fraction are compared with the literature data for 1-methyl-1-phenylcyclohexane (for which the following constants are indicated [8]: b. p. 93° (5 mm), d_4^{20} 0.9388, n_D^{20} 1.5233], it can be concluded that the studied fraction is mainly 1-methyl-1-phenylcyclohexane. This conclusion is also supported by the elementary analysis data for the fraction:

Found %: C 89.50, 89.47; H 10.45, 10.45. $C_{13}H_{18}$. Calculated %: C 89.53; H 10.47.

The aromatic fraction of the catalyzate obtained in the chromatographing on silica gel (with the exception of the earlier isolated 1-methyl-1-phenylcyclohexane fraction) was vacuum - distilled. The distillation results for this mixture of aromatic hydrocarbons (17.0 g) are presented in the table.

The method of oxidation with potassium permanganate [9] was used to determine the quantitative composition of the aromatic hydrocarbons contained in the studied fractions.

Fraction No.	Boiling range (at 8 mm)	d_4^{20}	n_D^{20}	Weight (in g)
1	99—106°	0.9890	1.5849	3.73
2	106—111	0.9935	1.5910	3.50
3	111—118	0.9991	1.5944	3.90
4	118—125	—	1.5990	0.84
5	125—145	1.0113	1.6130	2.70
	Residue	—	—	2.00
	Losses	—	—	0.33

Analysis of 1st - 3rd fractions: Found %: C 92.76, 92.79, H 7.27, 7.19. $C_{13}H_{12}$. Calculated %: C 91.81; H 7.19.

Analysis of 5th fraction: Found %: C 92.17, 92.22; H 7.82, 7.79. $C_{14}H_{14}$. Calculated %: C 92.25; H 7.75.

The method of oxidation with potassium permanganate [9] was used to determine the quantitative composition of the aromatic hydrocarbons contained in the studied fractions.

The oxidation of 1.8 g of mixed hydrocarbons from the 1st - 3rd fractions of the catalyzate gave 1.2 g of mixed acids with m.p. 103-150°. The mixed acids were subjected to fractional crystallization from aqueous-alcohol solution, as a result of which we isolated: 1) o-phenylbenzoic acid (0.11 g) with m.p. 112-114°, for which the literature gives m.p. 113.5 - 114.5° [7]; 2) m-phenylbenzoic acid (0.35 g) with m.p. 160-163°, for which the literature gives m. p. 165° [10]; and 3) an acid with m.p. 215-216°, the properties of which lie close to the properties of p-phenylbenzoic acid, for which a m.p. of 224° is given in the literature [10]. The fact that the phenylbenzoic acids are formed as the main products of the oxidation of the 1st-3rd fractions of the aromatic portion of the catalyzate is also supported by the titration of the acids obtained in the oxidation. The titration of 0.0420 g of mixed acids (which corresponds to 0.00021 mole of phenylbenzoic acid) in alcohol solution with sodium hydroxide, in the presence of phenolphthalein, required 2.10 ml of 0.1 N sodium hydroxide solution, i.e., a strictly equimolar amount of alkali with respect to the taken weight of phenylbenzoic acid.

The elementary analysis results obtained for the 1st-3rd fractions, and also the analysis results obtained for the oxidation products of these fractions, permit the conclusion that o-, m- and, apparently, p-tolylbenzenes are present in the investigated fractions. The oxidation of the 5th fraction [b.p. 125-145° (8 mm)] gave a mixture of acids with m.p. 230-275°. The titration of 0.0323 g of mixed acids required 2.28 ml of 0.1 N sodium hydroxide solution, which approximately corresponds to the amount of alkali that would be consumed for the titration of 0.0323 g of diphenyldicarboxylic acids.

The results of titrating the mixed acids, obtained in the oxidation of the 5th fraction, gave basis to postulate that the main oxidation products of the studied fraction are diphenyldicarboxylic acids, formed as the result of the oxidation of the ditolyls present in this fraction. The elementary analysis results obtained for the 5th fraction also suggest the presence of the ditolyls in it. However, since we were unable fractionally to crystallize the mixed acids obtained in the oxidation of the 5th fraction, it can only be postulated, and not considered proved, that ditolyls are present in the fraction.

The residue, obtained in the fractionation of the aromatic portion of the catalyzate — a slightly colored crystalline substance — after recrystallization from alcohol was found to consist of fluorene and phenanthrene.

SUMMARY

1. It was established that the contact transformations of dicycloheptyl in the presence of platinized carbon at 320° proceed with the formation of phenanthrene, fluorene, 1-methyl-1-cyclohexylcyclohexane, 1-methyl-1-phenylcyclohexane, tolylbenzenes and, apparently, isomeric ditolyls.

2. 1-Methyl-1-cyclohexylcyclohexane was synthesized and characterized for the first time.

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REACTION OF METAL OXIDES WITH ALCOHOLS

IV. VANADIUM OXIDES-ISOPROPYL ALCOHOL

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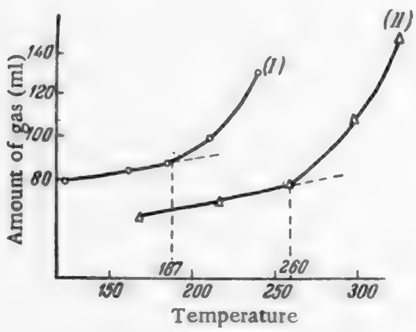
In studying catalytic reactions the attention is usually turned to a determination of the composition and structure of the obtained products. The possible changes in the composition of the catalyst remain outside the field of vision of the investigators. There is very little data in the literature on the changes in the chemical composition of a catalyst as a result of its operation. To obtain the indicated data is of undoubted theoretical interest and facilitates understanding the role of a catalyst as a substance showing direct participation in reactions.

Sabatier [1] found that many metal oxides when used as catalysts for the decomposition of alcohol suffer reduction. Later it was shown [2] that in the treatment of ethyl alcohol with WO_3 the latter is reduced to W_2O_5, in which connection the selective capacity of the oxide changes during the reduction process. When the catalyst of composition 35% V_2O_5 + 65% Al_2O_3 was investigated in the reaction for the hydrogenation of isobutylene it was shown that the V_2O_5 is reduced to V_2O_3, in which connection the maximum catalytic activity corresponds to the temperature at which the reduction of V_2O_5 to V_2O_3 proceeds at a maximum rate [3]. In our previous studies on the reaction of metal oxides with alcohols we studied the oxides of copper and iron [4]. It was shown that the copper oxide catalysts after operation always contain small amounts of cuprous oxide, dissolved, apparently, in the main mass of the copper metal. The oxides of iron (magnetite and hematite) in the process of their operation as catalysts for the decomposition of alcohols are converted into a mixture of the starting oxides and the product of their reduction – wüstite. Contradictory data [5], requiring verification, exist in the literature relative to the catalytic properties of vanadium oxide. The oxides of vanadium are characterized by a variable stoichiometric composition within definite limits, with retention in this connection of the crystalline structure [6]. Five phases exist in the system V-O: 1) V with oxygen dissolved in it up to the composition $VO_{0.46}$ crystallizing in the structure of a body-centered cube; 2) VO (NaCl type) of composition $VO_{0.88}$ – $VO_{1.36}$; 3) V_2O_3 (rhombohedral lattice of corundum) of composition $VO_{1.35}$ – $VO_{1.53}$; 4) VO_2 (lattice of rutile) of composition $VO_{0.85}$ – $VO_{2.05}$; and 5) V_2O_5, approximately corresponding to the stoichiometric composition. Consequently, besides an x-ray study of the oxides before and after their operation as catalysts for the catalytic decomposition of isopropyl alcohol, it was necessary to characterize the same oxides by chemical analysis methods. The oxides were analyzed by the method based on the reduction of an alkali salt of vanadium in sulfuric acid solution with sulfur dioxide and subsequent titration of the formed tetravalent vanadium with 0.1N permanganate solution [7]. To assure the possibility of calculating the "absolute activity", i.e., the activity per unit of surface, the specific surface of the oxides was determined after their operation as catalysts by the method of low-temperature adsorption of nitrogen vapors [8]. The usual type of apparatus was used to determine the catalytic activity of the indicated catalysts at two temperatures, which permitted calculating the apparent energy of activation (E_A) and gave an indication as to the influence of temperature on the selective capacity of the oxides in the catalytic decomposition of isopropyl alcohol. The temperature for the start of the catalytic reaction T_H was determined in advance from the gas-formation curve [9] (figure).

Two vanadium oxides were studied – V_2O_5 and V_2O_3. Vanadium pentoxide was obtained as a light-yellow powder by the prolonged heating of ammonium vanadate at 440° in a stream of dry air. Vanadium trioxide was obtained as a black powder in the reduction of V_2O_5 with hydrogen at 500°. Prior to use as catalysts the oxide powders were pelletized, after which the pellets were crushed into 4-5 pieces. The experimental results on the catalytic decomposition of isopropyl alcohol on the vanadium oxides are given in Table 1, and the characteristics of the vanadium catalysts are given in Table 2.

The data presented in Table 1 represent the average values of two-three separate experiments, usually showing good agreement with each other. From these data it follows that the reaction begins at a considerably lower temperature for vanadium penoxide than it does for vanadium trioxide. The character of the catalytic decomposition of isopropyl alcohol on the two oxides is different: V_2O_5 is primarily a dehydration catalyst, while V_2O_3 is primarily a dehydrogenation catalyst. The catalytic activity of vanadium trioxide is considerably lower than that of vanadium pentoxide. With elevation of the temperature the ratio of the dehydrogenation and dehydration reactions changes somewhat on the two oxides: on V_2O_5 the dehydrogenation is increased somewhat, while conversely, on V_2O_3 it is decreased somewhat. The ratio of the moles of hydrogen to the moles of acetone for the reaction on vanadium trioxide at both of the investigated temperatures is only slightly greater than one, which indicates the slight development of the subsequent reactions on this catalyst. In contrast to this, for vanadium pentoxide the indicated ratio at 240° is considerably less than one, and at 290° it is considerably greater than one. Apparently, on this oxide even at 290° the subsequent reactions show considerable development: the small value of the acetone to hydrogen ratio for 240° is explained by the consumption of the formed hydrogen for reducing the vanadium pentoxide. The energy of activation for the catalytic decomposition of isopropyl alcohol on V_2O_5 is considerably lower than for V_2O_3, which is in agreement with the temperatures at which reaction starts on these oxides.



Temperature at which isopropyl alcohol starts to decompose on vanadium pentoxide (I) and on vanadium trioxide (II).

The values of the filling weight, obtained by weighing 20 ml of oxides after running the catalytic reaction, are given in Table 2; also the data on the specific surface of the oxides, obtained by the method of using the isotherms of the low-temperature adsorption of nitrogen for calculation by the BET (Bureau of Temperature Standards) equation, and also the results of the chemical analysis and x-ray study of the vanadium oxides before and after their operation as catalysts in the above indicated reaction. The x-ray patterns of the oxides, obtained with chromium radiation at a current strength of 20ma and a voltage of 25kv with an exposure of 2 hours and 45 minutes, show that whereas the V_2O_3 failed to change its structure after operation as a catalyst, the V_2O_5 after operation already had a different lattice, corresponding, according to our measurements and calculations, to a lattice of the rutile type.

TABLE 1

Catalyst	Temperature at which reaction starts	Experimental temperature	Amount of alcohol passed (g)	Obtained: condensate (g)	Obtained: gas (ml)	Amount of acetone in condensate (%)	Composition of gas (in volume %): H	Composition of gas (in volume %): C_3H_6	$\frac{H_2}{CH_3COCH_3}$ (molar)	$\frac{C_3H_6}{H_2}$ (molar)
V_2O_5	187	240°	8	4.6	2000	17.76	4.9	96.7	0.32	19.0
		290	8.6	2.5	2800	28.5	17.5	82	1.77	20.8
V_2O_3	260	310	9.4	7.3	790	23.3	80	18	1.32	81.5
		360	8.6	6.0	1320	36.7	74.5	23	1.16	32

Catalyst	Temperature	Percent of alcohol decomposed	Activity of the catalyst (ml gas/g alcohol): Per ml of catalyst	Per g of catalyst	Per 10 m² of catalyst	Energy of activation	Sum of products accounted for
V_2O_5	240°	77	10.1	10.4	5.3	1810	100.4
	290	80	12.2	13.5	6.4		81
V_2O_3	310	23	3.7	4.4	2.4	8650	81
	360	36	6.55	7.8	4.3		73

TABLE 2

Oxide	Specific surface (m^2/g)	Filling weight (g/ml)	Chemical analysis results		Lattice structure	
			Before experiment	After experiment	Before experiment	After experiment
V_2O_5	19.00 20.80 } 19.9	0.97	~100% V_2O_5	~100% VO_2	Lattice of V_2O_5	Lattice of the rutile type (VO_2)
V_2O_3	21.5 19.5 } 20.5	0.845	~100% V_2O_3	~100% V_2O_3	Lattice of the corundum type (V_2O_3)	Lattice of the corundum type (V_2O_3)

The data presented in Table 2 show that during the catalytic reaction process the vanadium pentoxide is reduced to the dioxide, which can be seen from the results of the chemical and x-ray analysis. The vanadium trioxide apparently remains unchanged.

SUMMARY

Vanadium pentoxide, when used as a catalyst for the catalytic decomposition of isopropyl alcohol, is reduced to vanadium ~~pentoxide~~. Vanadium trioxide under the same conditions does not suffer a change in either its composition or structure. The selective capacity shown by the indicated vanadium oxides in this reaction is different and changes in a different manner with elevation of the temperature. The temperature for the start of isopropyl alcohol decomposition and the apparent energy of activation are considerably lower on vanadium pentoxide than on the trioxide.

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THE REACTION OF SILICON TETRAFLUORIDE WITH BENZYLMAGNESIUM CHLORIDE

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Replacement of atoms or radicals in a molecule by other atoms or radicals leads to a redistribution of the electron density and its accompanying change in the energy of each of the bonds between the atoms. Depending on the properties of the atoms or radicals being replaced and those replacing them, and the location of each bond inthe molecule, the energy of the former should either increase or decrease, and in connection with this the mobility of the corresponding atom or radical either increases or decreases. Having encountered fundamental objections [2], such representations do not depart from the assumption of the existence of a limiting saturation for atoms [1].

From this viewpoint it is easy to explain the course of the reaction of aryl- and alkylmagnesium halides and, in particular, of benzylmagnesium chloride with silicon tetrafluoride. Earlier one of us had established the formation of tribenzylfluoromonosilane together with tetrabenzylmonosilane as the end result of the mentioned reaction [3]. Further study revealed that an acceleration in the rate of passing the silicon tetrafluoride into the Grignard reagent, even when the process was run at a temperature above 0°, leads to a reduction in the relative yields of the tetrasubstituted derivative and the appearance of dibenzyldifluoromonosilane. The reaction proceeds in several phases: it is probable that the monobenzyl derivative is formed first, then the dibenzyl derivative, the tribenzyl and, finally, the tetrabenzyl derivative of the monosilane. The rate of these reactions decreases in measure with the substitution of fluorine atoms on the organic radicals, causing each time an increase in the energies of the bonds between the still-not-substituted fluorine atoms and the silicon atom and leading to an increase in the energy of activation. Such a change in the activity of arylfluoromonosilanes with respect to a Grignard reagent is in accord with the results of comparing the average values of the bond energies of silicon atoms with carbon atoms, on the one hand, and with fluorine atoms on the other; as is known, these values are lower in the first case than in the second.

To verify the stepwise character of the given reactions we studied the behavior of tribenzylfluoromonosilane toward an ether solution of benzylmagnesium chloride (at room temperature, or with heating, following the removal of the ether by distillation), and also the behavior of silicon tetrafluoride toward an ether solution of tetrabenzylmonosilane.

The temperature also exerts substantial influence on the character and ratio of the products obtained in the reaction of silicon tetrafluoride with a Grignard reagent. A reduction in temperature, retarding the rates of all of the examined reactions, exerts an especially marked influence on the slowest processes, which first leads to a reduction in the relative yields of tetrabenzylmonosilane, then of tribenzylfluoromonosilane, etc.

The considerations that we have presented should be studied in conjunction with the opinions expressed by A. Ya. Yakubovich and V. A. Ginsburg relative to the problem of the hydrolysis of the haloalkyl derivatives of silicon [4].

EXPERIMENTAL

Reaction of Benzylmagnesium Chloride With Silicon Tetrafluoride. Silicon tetrafluoride, obtained by heating 24 g of sodium silicofluoride with 12 g of powdered glass and 30 ml of concentrated sulfuric acid, was passed for 42 minutes, with shaking and ice water cooling, into a solution of benzylmagnesium chloride,

obtained from 56.9 g of benzyl chloride, 11 g of magnesium and 210 ml of absolute ether. After 21 hours, the reaction product was decomposed with 55 ml of 8% hydrochloric acid. The top ether layer was separated from the water layer, and the ether was distilled; the residual substance (31.7 g) was distilled up to a temperature of 200°. Repeated distillation of the residual substance (30.5 g) at 20 mm gave among others, three fractions boiling in the intervals 240-254° (0.85 g), 254-261° (11.65 g) and 261-267 g (1.21 g), which crystallized on cooling, and from which by recrystallization from alcohol we isolated 13 g (21.7%) of pure tribenzylfluorosilane with m.p. 79°, and only 0.11 g of tetrabenzylmonosilane. The fraction distilling up to 182° (10.35 g), gave as the result of repeated fractional distillation at 657 mm 7.76 g of colorless liquid, proving to be a mixture of dibenzyldifluoromonosilane with dibenzyl, and boiling at 289-291°. Repeated removal of the dibenzyl by freezing led to the isolation of nearly pure dibenzyldifluoromonosilane.

Found %: C 67.78; H 5.75; F 15.06. $C_{14}H_{14}F_2Si$. Calculated %: C 67.70; H 5.69; F 15.31.

Although dibenzyldifluoromonosilane is decomposed by water very slowly, giving an acid solution, still its reaction with sodium hydroxide solution or ammonia proceeded very rapidly.

Reaction of Tribenzylfluromonosilane with Benzylmagnesium Chloride. At Room Temperature. To the Grignard reagent prepared from 2.53 g of benzyl chloride, 0.49 g of magnesium and 11 ml of absolute ether, was added 3.20 g of tribenzylfluoromonosilane. After 5 days, the deposited colorless crystals were filtered, washed first with absolute ether, then with dilute hydrochloric acid, and finally with water. The crystals had m.p. 126-127.5° and proved to be nearly pure tetrabenzylmonosilane. The ether solution was decomposed with 6 ml of 8% hydrochloric acid. The substance remaining after distilling off the ether from the top ether layer crystallized (0.44 g); m.p. 124-127°. A total of 3.53 g (90%) of pure tetrabenzylmonosilane with m.p. 127.5° (from alcohol) was isolated.

With Heating at 180-185°. The same components and amounts were taken as in the previous case. After having added the tribenzylfluoromonosilane to the Grignard reagent the ether was distilled off and the solid residue was heated in a metal bath at 180-183° for 1 hour. After cooling the distilled ether was poured back into the reaction products. After decomposition with hydrochloric acid the ether was distilled on the water bath (without separating from the water layer). The precipitate found in the water layer was filtered under reduced pressure, washed with water (34 ml), then with ethyl ether (5 ml), and finally it was dissolved in boiling benzene. From the solution after filtration, cooling, etc., we isolated 3.80 g of pure tetrabenzylmonosilane with m.p. 127.5°. Yield 96.9%.

Behavior of Tetrabenzylmonosilane Toward Silicon Tetrafluoride. Silicon tetrafluoride, obtained as indicated above from 10 g of sodium silicofluoride, was passed into a solution of 3.20 g of tetrabenzylmonosilane in 60 ml of absolute ether for 1 hour, with ice water cooling. After distilling off the ether all of the taken tetrabenzylmonosilane was recovered unchanged.

SUMMARY

1. The reaction of silicon tetrafluoride with an ether solution of benzylmagnesium chloride at a temperature above 0° yields dibenzyldifluoromonosilane.

2. The reaction of benzylmagnesium chloride with tribenzylfluoromonosilane at room temperature, and with heating to 180-185°, gave tetrabenzylmonosilane in yields of 90 and 96.9%, respectively.

3. It was shown that tetrabenzylmonosilane does not react with silicon tetrafluoride in ether solution at 0°.

4. The stepwise character of the reaction of a Grignard reagent with silicon tetrafluoride was elucidated.

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CATALYTIC SYNTHESIS OF KETONES

VI. SYNTHESIS OF METHYL BUTYL AND ETHYL PHENYL KETONES

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In the present paper we continue our study of the application of the ketonization schemes proposed earlier [1, 2] to the examples of reacting benzoyl chloride with ethyl bromide and acetyl chloride with butyl bromide over aluminum oxide and wood (birch) charcoal. Analysis of the experimental data revealed that the formation of ketones from acid chlorides and alkyl halides does actually occur. Thus, from acetyl chloride and butyl bromide, in accord with the ketonization scheme, methyl n-butyl ketone and methyl sec-butyl ketone should have been obtained. Actually, the ketonization reaction proceeds mainly in the direction of forming methyl sec-butyl ketone, and only traces of methyl n-butyl ketone were found. Together with the methyl butyl ketones, acetone is also formed. The yield of methyl sec-butyl ketone was 10.8%, based on acetyl chloride. Such a small yield is probably explained by the fact that the catalyst was coated to a very high degree by carbonaceous deposits and was deactivated.

Benzoyl chloride and ethyl bromide should have given phenyl ethyl ketone, which was actually obtained in 17.8% yield, based on benzoyl chloride. With the exception of one case [1], the investigated ketonization reaction of acid chlorides and alkyl halides has not been described in the literature.

EXPERIMENTAL

Selection of Catalyst. The substances studied as catalysts were: asbestos wool, manganese chloride on asbestos, copper and the copper halides on asbestos, chromium oxide, aluminum oxide on asbestos wool, aluminum oxide prepared by the Karyakin method [3] from aluminum sulfate and chloride, activated granular charcoal and birch charcoal, and molybdenum oxide on asbestos wool. The most active catalysts proved to be aluminum oxide on asbestos wool, birch charcoal and manganese chloride.*

The Synthesis of Methyl Butyl Ketones from Acetyl Chloride and Butyl Bromide was run over aluminum oxide at 425°. The optimum temperature was established in advance. The catalyst was dried in a hydrogen stream. 100 ml of the starting mixture of CH_3COCl and $n\text{-}C_4H_9Br$ in a molar ratio of 1:1 was passed through the apparatus at a space velocity of 15 ml/hour. The obtained catalyzate (45 ml) was distilled into two fractions: 1st, 46-102° (composed of unreacted starting materials), and 2nd fraction with b.p. 102-132°.

From the 1st fraction we isolated acetone, b.p. 56-60°; its 2,4-dinitrophenylhydrazone had m.p. 126°, and the mixed m.p. failed to be depressed. From the 2nd fraction we isolated 4 ml of methyl sec-butyl ketone, b.p. 116-119°; its 2,4-dinitrophenylhydrazone had m.p. 113-114°, and the mixed m.p. failed to be depressed.

From the distilled residue of the 2nd fraction we obtained several drops of ketone, the 2,4-dinitrophenylhydrazone of which had m.p. 104-107°; its mixed melting point with the 2,4-dinitrophenylhydrazone of methyl n-butyl ketone was not depressed.

The ketonization of acetyl chloride at 420° over wood charcoal, previously dried in a hydrogen stream at 450°, gave acetone.

The Synthesis of Ethyl Phenyl Ketone from Benzoyl Chloride and Ethyl Bromide was run over aluminum

* The experiments were performed by T. B. Dyulger.

oxide and over wood charcoal at 425°. The passage rate for 50 ml of the mixture (1:1) was 15 ml/hour. The unreacted starting materials were removed by distillation, while the residue was distilled at 210-220°, and then treated with 10% sodium hydroxide solution. The ethyl phenyl ketone was extracted with ether. After distillation (5 g, 17.8%), it had the constants: b.p. 218 – 219°, m.p. 23°, n_D^{48} 1.515, d_4^{24} 1.034; the 2,4-dinitrophenylhydrazone had m.p. 191°. Its mixture with the authentic specimen did not depress the melting point. Ethyl phenyl ketone was not found when wood charcoal was used as the catalyst at 425°. Also benzophenone was not found.

SUMMARY

1. Methyl butyl ketone was synthesized from acetyl chloride and butyl bromide in 10.8% yield (based on acetyl chloride). From benzoyl chloride and ethyl bromide we obtained phenyl ethyl ketone in 17.8% yield (based on benzoyl chloride).

2. The application of the previous schemes to the synthesis of ketones from acid chlorides and alkyl halides was experimentally confirmed.

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CONJUGATED SYSTEMS

LXXI. DIMERIZATION OF FLUOROPRENE

A. A. Petrov and A. V. Tumanova

The dimerization of diene halo derivatives when heated has been studied but slightly [1]. The data found in the literature deal chiefly with chloroprene. The latter when heated, gives 4-chloro-1-vinyl-3-cyclohexene and a small amount of 4-chlorovinylcyclohexadiene [2]. In the still residues from the rectification of chloroprene, together with the above-mentioned six-membered dimer, was also found a dimer with an eight-membered ring, obtained later by the polymerization of chloroprene in the presence of phenothiazine and activated charcoal [3-5]. Six-membered dimers of 1-chloro- and 1-bromo-3-methylbutadiene [6, 7, 8] and the dimer of 2, 3-dichloro-1, 3-butadiene with an eight-membered ring [4] are also known. Data on the dimerization of diene fluoro derivatives are absent in the literature.

We ran some experiments on the dimerization of fluoroprene chiefly at 120°. In this case, by analogy with other dienes, the formation of four-, six- and eight-membered cyclic dimers could be expected. In addition, it was necessary to consider the possibility of cleaving hydrogen fluoride from some of the dimers, i.e., the appearance of cyclic diene halo derivatives in the reaction products, which could serve as a source for the formation of more complex bicyclic compounds.

To obtain the dimers we heated fluoroprene in the presence of an inhibitor (p-tertiary-butylcatechol) in glass tubes at 80, 100 and 120° for 1-3 days.

The dimerization hardly goes at 80°. At 120 after 1 day a 55-65% yield of dimer and a 25-30% yield of polymer are obtained, the remainder being the monomer. Most of our experiments were run at this last temperature. In all cases dimeric products were obtained that showed 85-90% distillation in a 2° range. A lower fraction, which could have contained the products of hydrogen fluoride cleavage from the dimers, was practically absent.

We investigated the main fraction with b.p. 146-148°. In its odor the substance is comparable to the dimer of divinyl. When kept under ordinary conditions it slightly etches glass and becomes cloudy. It can be kept for months in a sealed ampul (in the absence of air) without any visible changes. Evidently the liberation of hydrogen fluoride, responsible for the etching of glass, is conditioned by the action of atmospheric oxygen on the dimer and is not a property of the dimer itself.

To determine its structure the dimer was subjected to various chemical transformations.

1. Only 4% of the fluorine present in the taken weight goes into solution when the dimer is heated for 1 hour in 10% alcoholic caustic solution. Consequently, it fails to contain any appreciable amounts of isomers with the fluorine not at a double bond (at a tertiary carbon atom).

2. The oxidation of the dimer with potassium permanganate gave β-carboxyadipic acid. As a result, the dimer should be assigned a vinylcyclohexene structure. When the dimer was oxidized under more drastic conditions the formation of small amounts of succinic acid was observed. This fact is not unexpected, since other cyclohexene derivatives also form this acid when oxidized under sufficiently drastic conditions.

3. The cyclohexene structure of the dimer was supported by the experiments on the dehydrogenation of the substance over platinized carbon at 300°. The dehydrogenation proceeded with the loss of a major portion

of the fluorine as hydrogen fluoride and with the formation of a mixture of ethylbenzene and fluoroethylbenzenes. The oxidation of this mixture under various conditions gave either benzoic acid or a mixture of benzoic and fluorobenzoic acids, the separation of which proved difficult.

4. To determine the position of the fluorine the dimer was converted by a number of transformations into fluoro-Δ^3- tetrahydroacetophenone, which was extremely close in its properties to the condensation product of fluoroprene with methyl vinyl ketone, for which the para-position of the fluorine with respect to the acetyl group is without doubt. However, the hydrazine derivatives of these two ketones melted at different temperatures, and consequently the substance obtained from the dimer was not pure p-fluorotetrahydroacetophenone.

As a result, the investigated chemical properties of the fluoroprene dimer do not leave any doubts as to the fact that it is a fluoro-substituted 3-vinylcyclohexene. The position of the fluorine atom, however, remained unproved, although by analogy with chloroprene it fails to arouse any special doubts.

We also took the infrared spectrum of the fluoroprene dimer, where absorption bands, characteristic for the vinyl groups attached to a six-membered ring, were found (11-12 μ). A comparison of this spectrum with the spectra of divinyl-butane, vinylcyclohexene and cyclooctane leaves no doubts on the matter that the dimer had the structure of the second substance. The absorption bands, characteristic for vinyl-cyclohexene, in the case of the fluoroprene dimer prove to be shifted somewhat toward the longer wavelengths, evidently due to the presence of the fluorine atom (Fig. 1).

The infrared spectrum for one of the higher fractions of the dimer (120-140° at 100 mm) differed sharply from the spectrum of the main substance. The sharply defined bands, characteristic for vinyl groups, were absent in its spectrum. It could be postulated that this fraction contains an eight-membered dimer (Fig. 2).

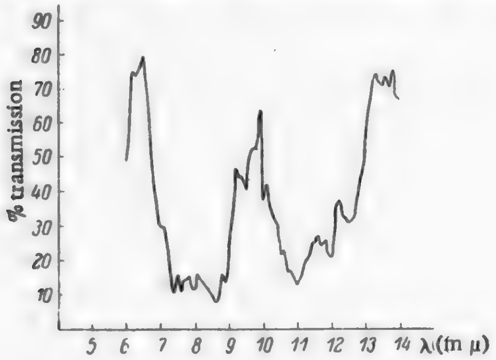

Fig. 1. Infrared spectrum of fluoroprene dimer (146-148° fraction).

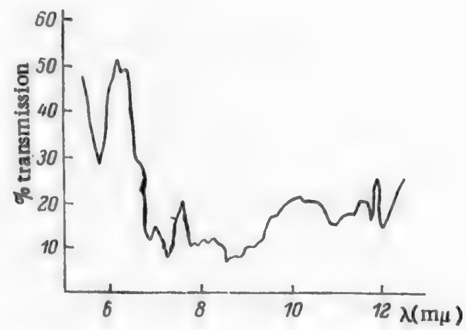

Fig. 2. Infrared spectrum of fluoroprene (fraction with b. p. 120-140° at 100 mm).

Some preliminary experiments were also performed on the joint "dimerization" of fluoroprene and divinyl. The joint "dimers" of diene hydrocarbons and halo derivatives have hardly been studied. Only a preliminary communication exists on the formation of such a product from divinyl and chloroprene [8].

Together with the dimers of divinyl and especially of fluoroprene, the heating of fluoroprene with divinyl also gave a joint "dimer". The substance contains hardly any saponifiable fluorine, and apparently has a six-membered ring, since it can be dehydrogenated on platinum.

EXPERIMENTAL

For the studies we used fluoroprene with b.p. about 12° (760 mm) and n_D^8 1.4010, stabilized with p-tertiary-butylcatechol. The fluoroprene was obtained by the method given in the literature [9].

The reactions were run in sealed glass tubes in a thermostat with a control accuracy of 1-2°. The condensation products were worked up as follows. First the unreacted monomer was distilled off on the water bath (collected in a coil receiver cooled with dry ice), and then the dimers were steam-distilled. The dimers were distilled through a column (30 cm) filled with glass packing.

The distillation of 113.6 g of products gave the fractions described in Table 1.

TABLE 1

Fraction Nos.	Boiling point at 100 mm	Yield (in %)	d_4^{20}	n_D^{20}	MR_D		% F	
					Found	Calculated	Found	Calculated
1	To 85°	1.5	1.0607	1.4375	35.64		—	—
2	85— 86	81.8	1.0644	1.4383	35.56	35.80	26.59	26.35
3	86— 88	3.9	1.0647	1.4400	35.69			
4	88— 90	1.2	1.0708	1.4415	35.59			
5	90—100	1.8	1.0789	1.4470	35.70			
6	100—120	1.8	1.0941	1.4535	35.65			
7	120—140	1.8	1.0911	1.4622	36.34*		25.83	26.35
8	Residue	3.3	—	—	—			

* The MR_D calculated for the dimer with an eight-membered ring was 36.35.

The molecular weights were determined for the main fraction (85-86° at 100 mm or 146-148° at 760 mm) and the fraction with b. p. 120-140° at 100 mm).

2nd fraction. Found: M 144.1, 145.8. $C_8H_{10}F_2$. Calculated: M 144.2.
7th fraction. Found: M 146, 144. $C_8H_{10}F_2$. Calculated: M 144.2.

To an emulsion of the fluoroprene dimer in 100 ml of water, cooled to 15-20°, with vigorous stirring was added in small portions 51.2 g of potassium permanganate. The excess permanganate was tied up with manganese sulfate. SO_2 gas was used to render the manganese oxides soluble. The acids were extracted with ether. Removal of the ether by evaporation gave about 0.2 g of crystals with m.p. 182-183° (from hot water). The mixed melting point with authentic succinic acid was not depressed.

The liquid from the ether extraction was acidified with sulfuric acid and again extracted with ether. Here 2.5 g of crystals with m. p. 105-110° was obtained. The substance is readily soluble in acetone and insoluble in benzene. After repeated recrystallization from a mixture of these solvents and thorough drying over $CaCl_2$ an acid with m.p. 113-115° was obtained, which corresponds to the literature data for β-carboxyadipic acid [10].

Found %: C 44.86; H 5.23. $C_7H_{10}O_6$. Calculated %: C 44.21; H 5.26.

The oxidation of the dimer in aqueous acetone solution or in a water suspension in weakly alkaline solution (in the presence of K_2CO_3) with 4-5% potassium permanganate solution at a temperature not exceeding 10° gave only the β-carboxyadipic acid with m.p. 115-118°.

Twenty grams of the dimer was dehydrogenated by passing it at a rate of 2-3 drops a minute through a tube containing platinized charcoal at 300°. Here 14.5 g of oil was obtained, which gave the following fractions when distilled: 1st, to 141°, 2.2 g; 2nd 141 – 143°, 6 g; 3rd 143 – 150°, 3.2 g; residue – 1.7 g.

Found for the 2nd fraction: d_4^{20} 0.9824, n_D^{20} 1.4740.

Found %: F 14.95. C_8H_9F. Calculated %: F 15.20.

Literature data for p-fluoroethylbenzene [11]: b.p. 141°, d_4^{20} 0.967.

Oxidation of the substance with 25% nitric acid gave a mixture of benzoic and fluorobenzoic acids with m.p. 125-150° and a fluorine content of 7.91%, as compared to the 13.56% calculated for fluorobenzoic acid.

The oxidation of 7.7 g of the same fraction of dehydrogenation products (from a different experiment) with 39 g of potassium permanganate in 700 ml of water under prolonged boiling of the mixture gave 2.5 g of crystals with m. p. 120-122° (from hot water). The mixed melting point with authentic benzoic acid was not depressed.

To convert the fluoroprene dimer into fluorotetrahydroacetophenone the former was treated with N,N-dibromobenzenesulfonamide in methyl alcohol. The reaction products were steam-distilled. The bromoester obtained in this manner was heated with mossy zinc in acetic acid.

On conclusion of violent reaction the mixture was heated under reflux for 15 minutes, and the reaction products were steam-distilled. The oily layer was separated, washed with soda solution, and dried over $CaCl_2$. From 6.2 g of the dimer we obtained 4.2 g of p-fluoro-Δ^3-tetrahydroacetophenone with the following constants.

B.p. 94.5 – 95.5° (20 mm), d_4^{20} 1.0695, n_D^{20} 1.4580, MR_D 36.23; calc. 36.34. Found %: F 13.28. $C_8H_{11}OF$. Calculated %: F 13.36.

The semicarbazone of this ketone had m. p. 156-157° (from water). Found %: N 21.45. $C_9H_{14}ON_3F$. Calculated %: N 21.10.

The 2, 4-dinitrophenylhydrazone melted at 122-124°. Found %: N 17.68 $C_{14}H_{15}O_4N_4F$. Calculated %: N 17.39.

Literature data for p-fluoro-Δ^3-tetrahydroacetophenone [12]: b.p. 95 – 95.5° (20 mm), d_4^{20} 1.0705, n_D^{20} 1.4565. Semicarbazone: m.p. 170-172°; 2, 4-dinitrophenylhydrazone: m.p. 141-144°.

A Hilger spectrometer (model D-88 with a rock salt prism) was used to take the infrared spectra of the two fractions of the dimer. A nichrome ribbon served as the radiation source. The galvanometer mirror readings were made visually with the aid of an optical tube. The measurements were made in the range from 6 to 14 μ at 0.1 μ intervals. The substance was pressed between the rock salt sheets. The layer thickness was 30-50 μ. The obtained data are shown in Figs. 1 and 2.

The heating of 100 ml of an equimolar mixture of divinyl and fluoroprene at 120° for 1 day gave 44 g of an oil and 18.5 g of polymers. The heating of the same mixture for 3 days gave 37.7 g of an oil and 42.1 g of polymers.

Distillation of 97.2 g of the oil gave the results shown in Table 2.

TABLE 2

Fraction Nos.	Boiling point	Weight (in g)	d_4^{20}	n_D^{20}
1	60—129°	2.0	1.0523	1.4510
2	129—132	5.5	0.8925	1.4538
3	132—135	10.6	0.9277	1.4530
4	135—138	29.3	0.9601	1.4490
5	138—140	6.1	0.9783	1.4469
6	140—143	10.4	1.0046	1.4445
7	143—148	14.7	1.0288	1.4450
8	Residue	3.0		

4th Fraction. Found %: F 12.35, 12.56. $C_8H_{11}F$. Calculated %: F 15.05.

9.5 g of the joint "dimer" (135-138° fraction) was passed at 300° over platinized charcoal in a CO_2 stream. The evolution of hydrogen fluoride was observed. Here 6.3 g of oil was obtained, which separated into the following fractions when distilled: 1st, 135-137°, 3.8 g; 2nd, 137-138°, 1.5 g; residue – 0.7 g.

1st Fraction had d_4^{20} 0.9104, n_D^{20} 1.4828. Found %: F 7.68, 7.03. C_8H_9F. Calculated %: F 15.20.

The oxidation of this fraction with nitric acid gave a mixture of benzoic and fluorobenzoic acids with m.p. 152-163°.

SUMMARY

1. The dimerization of fluoroprene at 120° was studied.

2. It was established that a dimer of the Lebedev type is obtained under these conditions, apparently being p-fluorofluorovinylcyclohexene.

3. It was shown that fluoroprene is capable of condensing with divinyl with the formation of the same type of dimer.

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THE ORDER OF ADDITION OF BROMINE HYDROGEN BROMIDE AND ALKYL HYPOBROMITES TO ALLYLMETHYLACETYLENE (HEXENE-1-YNE-4)

A. A. Petrov

Allylacetylene (pentene-1-yne-4) adds on bromine at the double bond [1] while vinylacetylene adds bromine at the triple bond and in the 1,4-position [2]. The less reactive triple bond is activated in this case as a result of conjugation with the double bond. At the same time, vinylalkylacetylenes of the type R–C≡C–CH=CH_2, in spite of the fact that conjugation of the multiple bonds again takes place, add on bromine almost exclusively at the double bond [3].

The triple bond is more reactive toward hydrogen and hydrogen halides in both vinylacetylene and the vinylalkylacetylenes [4,5]. Hypohalites, on the contrary, add on to vinylalkylacetylenes at the double bond [6,7].

In a continuation of research aimed at explaining these experimental regularities, we have made a study of the order of addition of bromine, hydrogen bromide and alkyl hypobromites to allylmethylacetylene (hexene-1-yne-4). The nature of the double and triple bonds in this hydrocarbon is the same as in the case of vinylmethylacetylene; they are, however, not conjugated.

Allylmethylacetylene has recently been described as a product of the pyrolysis of the acetate of hexene-4-ol-1 [8]. In the present work it was prepared by the action of allyl bromide on methylacetylenyl bromide in ether solution in the presence of cuprous chloride. Practically no reaction takes place in the absence of catalyst.

The structure of the hydrocarbon has been established beyond doubt. First of all, it is determined by the synthesis method. Six structural isomers are possible for the vinylacetylenic hydrocarbon C_6H_8. Since the hydrocarbon being studied did not react with ammoniacal silver oxide solution, all the formulas with a terminal acetylenic group are excluded. The absence of any exaltation of the molecular refraction and the low refractive index lead to the rejection of two other formulas with a conjugated system of multiple bonds: the hydrocarbon differs markedly in all its constants from the vinylethylacetylene described in the literature.

Thus the only formula which can be given to this substance is that of allylmethylacetylene. This structure for the hydrocarbon has been confirmed by the Raman spectrum, which at almost all frequencies is the sum of the spectra for monosubstituted ethylene and disubstituted acetylene.

When the allylmethylacetylene was brominated in chloroform, only one dibromide was obtained, with a constant boiling point somewhat higher than that found earlier for vinylethylacetylene dibromide. Further bromination leads to the formation of a tetrabromide.

The structure of the tetrabomide has been established beyond doubt (1,2,4,5-tetrabromohexene-4). The structure of the dibromide has been established from a study of its infra-red and Raman spectra, in which were found only the frequencies characteristic of acetylenic compounds (infra-red spectrum – 2252 cm^{-1}, Raman spectrum – 2244, 2316 cm^{-1}). The double bond is practically absent from the compound (the substance does not absorb in the region around 1600 cm^{-1}). The infra-red spectrum of the dibromide is given in the figure (Curve 1).

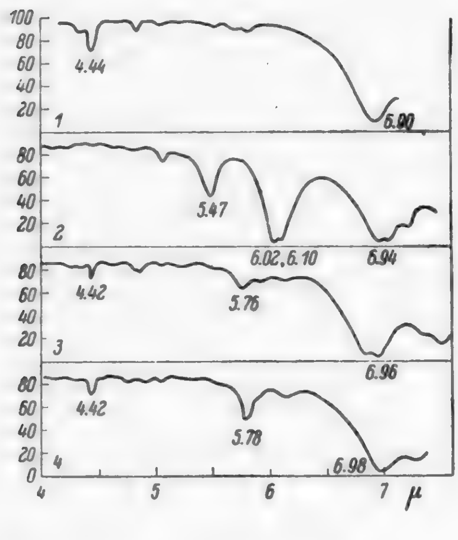
The dibromide is thus 1,2-dibromohexyne-4

In agreement with this structure, the dibromide reacts (even in the cold) with alcoholic alkali, approximately 75% of the bromine being transferred to the solution. As a result of the reaction a mixture of monobromide (I or II) and ether (IV) is obtained:

$$CH_3-C\equiv C-CH_2-CBr=CH_2 \quad (I), \qquad CH_3-C\equiv C-CH_2-CH=CHBr, \quad (II)$$
$$CH_3-C\equiv C-CH=CH-CH_2Br \quad (III), \qquad CH_3-C\equiv C-CH=CH-CH_2OR. \quad (IV)$$

This result is quite understandable, if we take into consideration the fact that dehalogenation may take place in three ways, since there are three labile hydrogen atoms in the dibromide molecule [9]. Further reaction of the monohydrides (I) and (II) with alcoholic alkali is unlikely since they have a bromine atom on the double bond. The monobromide (III) has allylic character and is consequently able to react with alcoholic alkali with easy replacement of the bromine by alkoxyl and formation of the ether (IV).

The addition of hydrogen bromide to allylmethylacetylene was carried out very readily by simply stirring the hydrocarbon with highly concentrated hydrobromic acid (68% HBr). With acid of the usual concentration (approximately 50%), the reaction takes place very slowly, but it may be accelerated by the addition of the catalyst Cu_2Br_2.



Infra-red transmission spectrum (%):
1) $C_6H_8 + Br_2$, 2) C_6H_8 + HBr, 3) $C_6H_8 + CH_3OBr$, 4) $C_6H_8 + C_2H_5OBr$.
Layer thickness 0.1 mm up to 5 μ with LiF prism, beyond – with NaCl prism.

The infra-red spectrum and Raman spectrum of the hydrobromide showed intense frequencies characteristic of the double bond (1640 and 1660 cm^{-1}) and very weak ones (doubtful) for the triple bond. The hydrobromide proved to be stable toward alcoholic alkali and after oxonization and the usual treatment of the ozonides gave acetic acid, formaldehyde and a very small quantity of a bromine-containing acid, possibly β-bromobutyric acid.

It has thus been proved that the substance is 4- or 5-bromohexadiene-1,4, with possibly a slight trace of other isomers, so that hydrogen bromide adds on to allylmethylacetylene predominantly at the triple bond.

The action of benzenesulfodibromamide on a solution of allylmethylacetylene in methyl and ethyl alcohol led to the formation of the methyl and ethyl β-bromoethers.

The infra-red spectra of these substances show fairly well-defined absorption bands corresponding to those of the triple bond (2262 cm^{-1}). Very weak absorption was observed in the region of double bond frequencies around 1626 cm^{-1}).

The action of dinitrophenylhydrazine on these bromoethers in acid solution led to the formation of only insignificant amounts of a yellow precipitate, which indicates the presence of slight traces of the products of hypobromite addition at the triple bond.

In reaction with alcoholic alkali the bromoethers split off hydrogen bromide with the formation of enolic ethers, which undergo hydrolysis in the presence of dilute sulfuric acid, forming a ketone. The enolic ethers and the ketone could not, however, be obtained in the pure state.

It has thus been established that alkylhypobromites add on to allylmethylacetylene predominantly at the double bond.

A comparison of the experimental data obtained on the order of addition of bromine, hydrogen bromide and alkyl hypobromites to allylmethylacetylene with the data on the order of addition of the same substances to the isomeric vinylethylacetylene leads to the conclusion that both hydrocarbons behave in principle in the same way.

EXPERIMENTAL

The preparation of allylmethylacetylene. Methylacetylene was passed through an ether solution of the organomagnesium compound obtained from 1.5 mole magnesium and ethyl bromide, until absorption of the methylacetylene had ceased. The methylacetylene which had not reacted was collected in a coiled receiver cooled with solid carbon dioxide and passed again through the reaction mixture. (The methylene was obtained from 1,2-dibromopropane by the action of a solution of KOH in cellosolve or butyl alcohol with heating until the mixture boiled. The dibromide was added dropwise to the alkali solution at such a rate that smooth evolution of methylacetylene took place).

Approximately 40 g Cu_2Cl_2 was added to the reaction mixture obtained, followed by 1 mole of allyl bromide, added dropwise. Reaction took place with the evolution of heat. After the mixture had been stirred for 10 hours with the ether boiling gently, it was poured onto ice and the basic magnesium salts were dissolved in hydrochloric acid. The ether solution of the hydrocarbon was fractionated on a Widmer column (80 cm). The yield of allylmethylacetylene was 60-65% calculated from the allyl bromide.

B.p. 86-86.5° (750mm), d_4^{20} 0.7630, n_D^{20} 1.4368, MR 27.50; calc. 27.44.
Found %: C 89.85; H 9.79. C_6H_8. Calculated %: C 89.94; H 10.06.

Raman spectrum: 367 (4), 407 (4), 462 (2 broad), 920 (4 broad), 992 (3), 1299 (6), 1328 (4), 1382 (6), 1425 (4), 1642 (8), 2240(10 broad), 2303(10), 2451(2),2896(6), 2923(8), 2961(2), 3018(6), 3048(8), 3093(4) cm^{-1}.
Literature data [8]: b.p. 87° (753mm), d_{14}^{14} 0.767, n_D^{14} 1.4460. Characteristic frequencies in the Raman spectrum: 1643, 2241, 2303 cm^{-1}.

The hydrocarbon fraction boiling below 86° contained a slight trace of the original allyl bromide.

The bromination of allylmethylacetylene. a) 0.2 mole bromine in 50 ml chloroform was added dropwise with cooling by ice to a solution of 0.3 mole of the hydrocarbon in 150 ml chloroform. When reaction had finished the chloroform was distilled off on the water bath and the reaction product vacuum distilled. The yield of 1,2-dibromohexyne-4 was 81%, calculated on the bromine. The residue was 1,2,4,5-tetrabromohexene--4.

The dibromide was a pale yellow oil.

B.p. 93-93.5° (10 mm), 106-106.5° (20 mm), d_4^{20} 1.7244, n_D^{20} 1.5428, MR 43.85; calc. 43.44
Found %: C 30.31; H 3.31; Br 66.98, 66.53. $C_6H_8Br_2$. Calculated %: C 30.03; H 3.36; Br 66.61.

Raman spectrum: 327 (2), 384 (4 broad), 553 (2), 602 (2), 653 (8), 852 (2), 1244 (6), 1380 (4), 1424 (4), 2244 (8 broad), 2316 (6), 2456 (6), 2916 (8), 2973 (6) cm^{-1}.
The spectrum was not complete because of the yellow color of the substance.

The infra-red spectrum is given in the figure (Curve 1).

When 15 g of the dibromide was treated with a solution of 3 g KOH in 20 ml methyl alcohol, the temperature rose spontaneously to 55° while a voluminous precipitate of potassium bromide was formed. After standing for 1 hour the mixture was heated to boiling for 15 minutes and then diluted with water. The oil precipitated weighed 7 g. 7.7 g of bromide ion was found in the solution as against the 5 g calculated theoretically for 1 atom of bromine.

B.p. 152-157°, 56-60° (20 mm), d_4^{20} 1.0355, n_D^{20} 1.4855.
Found %: Br 22.32; OCH_3 15.90.

On the basis of these data the material contains approximately 44% monobromide and 56% of the ether

$C_6H_7OCH_3$. From the amount of bromide ion found in the solution the material should contain approximately 46% monobromide, which is within the limits of experimental error for these determinations.

b) 0.1 mole bromine was added to a solution of 0.05 mole of the hydrocarbon in 50 ml chloroform. After distillation of the chloroform 18 g (90%) of 1,2,4,5-tetrabromohexene-4 was obtained in the form of a heavy oil.

B.p. 154.5-155° (10 mm), d_4^{20} 2.2698, n_D^{20} 1.6010, MR 60.33; calc. 60.50.
Found %: Br 80.07, 79.83. $C_6H_8Br_4$. Calculated %: Br 79.97.

The addition of hydrogen bromide. 16 g allylmethylacetylene was stirred for 3 hours with 25 ml 68% hydrobromic acid. On distillation of the reaction product the following fractions were obtained: 1st 85-90°, 3.5 g (original hydrocarbon); 2nd 90-133°, 1 g; 3rd 133-133.5°, 14 g; 4th 133.5-180°, 2.5 g; residue – 7.3 g. Yield of 4- or 5-bromohexadiene-1,4 60%.

B.p. 133-133.5° (756 mm), d_4^{20} 1.2516, n_D^{20} 1.4830, MR 36.75; calc. 36.74.
Found %: C 44.74; H 5.55; Br 49.78. C_6H_9Br. Calculated %: C 44.74; H 5.63; Br 49.61.

Raman spectrum: 295 (1 broad), 407 (1 broad), 503 (3), 535 (3), 927 (2), 1206 (1), 1293 (5 broad), 1376 (4), 1411 (4), 1438 (4), 1640 (7), 1662 (8), 2239 (1 broad ?), 2894 (3), 2916 (5), 3016 (4), 3080 (2) cm^{-1}.

The infra-red spectrum is given in the figure (Curve 2).

When the hydrocarbon was stirred with more dilute acid (55%) in the presence of Cu_2Br_2 the same hydrobromide was obtained (b.p. 133-133.5°, d_4^{20} 1.2519, n_D^{20} 1.4830).

When 3.2 g of the hydrobromide in a two-fold excess of alcoholic KOH solution was left to stand for 3 hours at room temperature, 3.75% (0.06 g) of the bromide present in the sample was transferred to the solution. When 2 g of the hydrobromide in a two-fold excess of 10% alcoholic KOH was boiled for 0.5 hours, 40% of the bromine was transferred to the solution.

4 g of the hydrobromide was ozonized. Formaldehyde was determined in a sample of the ozonide as dinaphthomethane. The remaining part of the ozonide was treated in the usual way. Acetic acid was found and its silver salt analyzed.

Found %: Ag 64.52. $C_2H_3O_2Ag$. Calculated %: Ag 64.63.

The residue after distillation of the acetic acid (0.55 g) had the form of an oil which solidified on cooling. This was possibly bromobutyric acid.

Found %: Br 48.03. $C_4H_7O_2Br$. Calculated %: Br 47.85.

The addition of methyl hypobromite. 26.9 g (70%) of the bromoether and 4 g of a product with higher boiling point were obtained by the action of 36 g benzenesulfodibromamide on a solution of 17 g of allylmethylacetylene in 200 ml methyl alcohol, followed by steam distillation of the reaction product, separation and drying over $CaCl_2$ and vacuum distillation. The bromoether (evidently for the most part 1-bromo-2-methoxyhexyne-4) had:

B.p. 82-83° (10 mm), 96-97° (20 mm), d_4^{20} 1.3131, n_D^{20} 1.4880, MR 41.93; calc. 41.93.
Found %: C 43.72; H 5.70; Br 42.39. $C_7H_{11}OBr$. Calculated %: C 44.00; H 5.80; Br 41.82.

The infra-red spectrum is given in the figure (Curve 3).

The substance gave a weak reaction for the carbonyl group with 2,4-dinitrophenylhydrazine. The yellow substance obtained was difficult to purify.

The reaction of a solution of 5 g KOH in 25 ml methyl alcohol with 7.5 g of the bromoether (with boiling for 1 hour) yielded 3 g of a substance with b.p. 57-58° (20 mm), n_D^{20} 1.4815. Analyses gave lower results for carbon and hydrogen than required by the formula $C_7H_{10}O$. When this product was stirred with 5% sulfuric acid solution, partial hydrolysis took place, yielding a substance which boiled over a wide range (86-92° at 75 mm) and had n_D^{20} 1.4630, and which reacted with carbonyl group reagents.

The addition of ethyl hypobromite. The action of benzenesulfodibromamide on a solution of allylmethylacetylene in ethyl alcohol yielded the ethyl bromoether (evidently for the most part 1-bromo-2-ethoxyhexyne-4) in 56% yield.

B.p. 89-89.5° (10 mm), 103.5-104° (20 mm), d_4^{20} 1.2669, n_D^{20} 1.4830, MR 46.24; calc. 46.55.
Found %: C 46.50; H 6.31; Br 40.28; OC_2H_5 22.47. $C_8H_{13}OBr$. Calculated %: C 46.84; H 6.39; Br 38.96; OC_2H_5 21.97.

SUMMARY

1. Allylmethylacetylene (hexene-1-yne-4) has been prepared by the action of allyl bromide on methylacetylenyl magnesium bromide.

2. The order of addition of bromine, hydrogen bromide and methyl and ethyl hypobromites to this hydrocarbon has been studied.

3. Bromination of the hydrocarbon yielded 1,2-dibromohexyne-4 and 1,2,4,5-tetrabromohexene-4; the action of hydrogen bromide yielded 4- or 5-bromohexadiene-1,4. The structure of the first and last of these bromides has been established from chemical data and a study of their infra-red and Raman spectra.

4. The action of benzenesulfodibromamide on alcohol solutions of allylmethylacetylene yielded two bromoethers, which have been characterized by the same methods as substances containing for the most part the products of the addition of the alkyl hypobromites to the ethylenic link.

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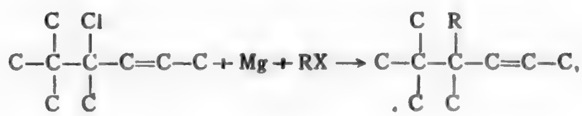
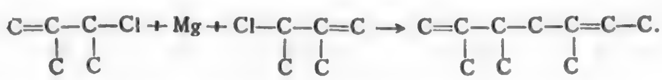
THE SYNTHESIS OF 2,2,3,5,6,8,9,9-OCTAMETHYLDECADIENE-3,7, 3,5,6,6-TETRAMETHYL-2-CARBOXY-4-HEPTENIC ACID-1 AND 3,5,6,6-TETRAMETHYL-4-HEPTENIC ACID-1

A. D. Petrov, V. N. Gramenitskaya and M. P. Shebanova

It has recently been shown [1] that a tertiary halide of the allylic type – 2,2,3-trimethyl-3-chlorohexene-4 condenses with primary halides in the presence of magnesium according to the scheme:



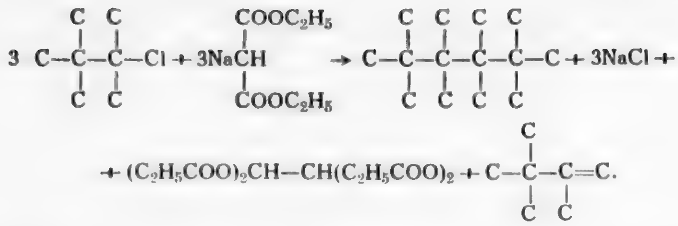
where R = allyl and propyl, i.e. without allylic rearrangement. In the case of the condensation under the influence of magnesium of two molecules of a secondary halide of the allylic type (3-chloro-2-methylbutene-1), however, only 2,3,5-trimethylheptadiene-1,5 is formed as a result of the allylic rearrangement of one of the molecules of the original chloride [2]:



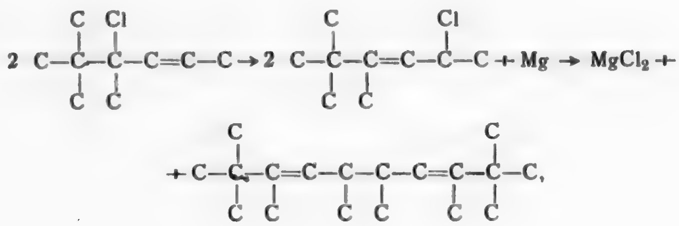
The isomerization may be reduced by replacing the magnesium by sodium and almost completely avoided by replacing it with potassium.

The aim of the present work was to study the nature of the condensation of two molecules of a tertiary halide of the allylic type – 2,2,3-trimethyl-3-chlorohexene-4: a) under the influence of magnesium, and b) under the influence of Na-malonic ester.* As is known [3], the action of Na-malonic ester leads to the condensation of two molecules of an original tertiary, but saturated, halide (triptyl chloride) (2-chloro-2,3,3-trimethylbutane with the formation of 2,2,3,3,4,4,5,5-octamethylhexane in 18% yield according to the scheme:

* The use of free Na and K for the condensation of tertiary alkyl halides is not possible as it leads to quantitative removal of hydrogen chloride.

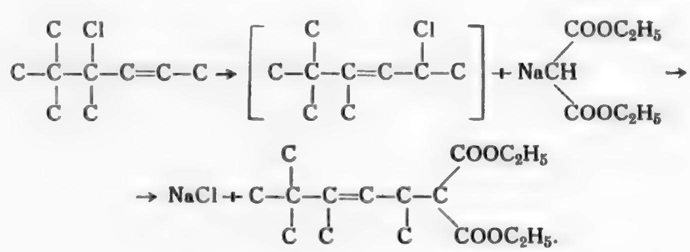


In the condensation of the first type—under the influence of magnesium—we observed the allylic rearrangement of both tertiary halide molecules with the formation of 2,2,3,5,6,8,9,9-octamethyldecadiene-3,7:



as proved by the formation of pinacolone and dimethylsuccinic acid with isomerization of only one halide molecule, acetic acid and a dibasic acid with a C_{10} chain (dimethyl-tert-butylsuccinic) would have been formed instead of dimethylsuccinic acid).

An unexpected result was obtained in the condensation of the second type, where instead of the expected hydrocarbon with four consecutive quaternary carbon atoms (2,2,3,4,5,5-hexamethyl-3,4-dipropenyl-hexane) we obtained the diethyl ester of 3,5,6,6-tetramethyl-2-carboxy-4-heptenic acid-1:



The ester was hydrolyzed to the dibasic acid, which was decarboxylated to give 3,5,6,6-tetramethyl-4-heptenic acid-1.

EXPERIMENTAL

The synthesis of 2,2,3,5,6,8,9,9-octamethyldecadiene-3,7. The hydrocarbon was obtained by the condensation, in the presence of magnesium, of two molecules of 2,2,3-trimethyl-3-chlorohexene-4 prepared

earlier [1] by treating 2,2,3-trimethyl-3-hydroxyhexene-4 with hydrogen chloride. The latter was synthesized by Yavorsky's method from 92 g (3.8 g-atom) magnesium, 201 g (2 mole) pinacolone, 230 g (30.1 mole) allyl chloride and 500 ml absolute ether. 238 g (84%) of the alcohol was obtained.

B.p. 168-170° (745 mm), n_D^{20} 1.4660,* d_4^{20} 0.8553, MR_D 44.62; calc. 44.82.

Treatment of 238.4 g (1.68 mole) of alcohol with hydrogen chloride yielded 191.3 g (71.5%) of 2,2,3-trimethyl-3-chlorohexene-4.

B.p. 45-46° (5 mm), n_D^{20} 1.4570, d_4^{20} 0.9043,** MR_D 48.12; calc. 48.16.
Found %: Cl 21.80, 21.72. $C_9H_{17}Cl$. Calculated %: Cl 22.06.

A solution of 120 g (0.75 mole) of the chloride in 200 ml absolute ether was added over a period of 4 hours at the temperature of boiling ether to 24 g magnesium in 400 ml absolute ether. When all the chloride had been added, the reaction mixture was stirred at the same temperature for 8 days. The reaction products were broken up with water. The organic layer and three ether extracts from the water layer were dried with Na_2SO_4 the ether was distilled off, and 19.09 g (20.4% calculated from the original chloride) of a fraction boiling at 115-120° (4 mm) was separated after two vacuum distillations. The substance solidified with the formation of crystals at −9 to −10°.

d_4^{20} 1.8401, n_D^{20} 1.4630, MR_D 84.12; calc. 84.39.
Found %: C 86.04, 86.25; H 13.78, 13.79. $C_{18}H_{34}$. Calculated %: C 86.31; H 13.69.

9 g of the hydrocarbon was oxidized with 1% $KMnO_4$ solution for 24 hours. The oxidation products were steam distilled. The aqueous distillate was shown to contain pinacolone by precipitation of a 2,4-dinitrophenylhydrazone with m.p. 125°, which was not lowered after 3 recrystallizations. The acid products were shown to contain acetic acid by the color reaction with $FeCl_3$ [5], formic acid by the white precipitate of calomel [5] and dimethylsuccinic acid by the precipitation of its Ag-salt.

Found %: Ag 59.87, 59.82. $C_6H_8O_4Ag_2$. Calculated %: Ag 59.90.

The reaction of 2,2,3-trimethyl-3-chlorohexene-4 with the Na-derivative of diethyl malonate. 1) 3,5,6,6-Tetramethyl-2-carboxy-4-heptenic acid-1. The mono-Na-derivative of malonic ester was obtained from 194 g (1.13 mole) malonic ester and sodium ethoxide. The sodium ethoxide was prepared from 25.95 g (1.13 g-atom) Na and 196.8 g (4.2 mole) ethyl alcohol, dehydrated over $CuSO_4$ and Na [6]. 191.3 g (1.19 mole) 2,2,3-trimethyl-3-chlorohexene-4 was added to the Na-derivative of malonic ester. The mixture was stirred vigorously, sealed into ampoules (with the liquid half-filling the ampoules) and heated in these for 45 hours on a glycerol bath at 100-108°. 5-10 minutes after heating had started, a considerable precipitate of NaCl formed in the ampoules. The reaction products were washed free from alcohol first with cold and then with hot water, then dried over Na_2SO_4 and vacuum distilled. This yielded 100.2 g of diolefin with b.p. 34.8-36° (5 mm), n_D^{20} 1.4308, d_4^{20} 0.7510, MR_D 42.59; calc. 42.88***; 142.3 g malonic ester with b.p. 71-73° (5 mm), n_D^{20} 1.4150, d_4^{20} 1.0552, MR_D 38.01; calc. 37.83**** and 72.58 g of a fraction with b.p. 130-135° (5 mm), n_D^{20} 1.4553, d_4^{20} 0.9513. 42.1 g of the last fraction was hydrolyzed with aqueous KOH solution [9] for 11.5 hours with heating on a boiling water bath. This yielded 23.6 g of crystalline acid $C_{12}H_{20}O_4$ (74% yield, calculated from the pure ester $C_{16}H_{28}O_4$). The acid could not be recrystallized from benzene, methyl alcohol, 96% ethyl alcohol or aqueous alcohol solutions. Pure crystals were obtained in the form of thin white needles only after 5-6 days from an aqueous solution prepared by boiling 1 g crystals in 5-6 ml water for 8 hours. M.p. 135°.

Found %: C 64.05, 63.76; H 8.80, 8.80. $C_{12}H_{20}O_4$. Calculated %: C 63.14; H 8.83

A sample of the acid was dissolved in 10 ml 96% ethyl alcohol and titrated with 0.1 N NaOH solution using thymol blue indicator. The basicity values found for the acid were 2.0 and 1.99.

The silver salt of the acid was prepared from a saturated aqueous solution of the acid. Since the salt is fairly readily soluble in water, the acid and $AgNO_3$ solution had to be evaporated further.

* Literature data: B.p. 168.4°, n_D^{20} 1.4476, d_4^{20} 0.85508 [4].
** Literature data: B.p. 46-47° (6 mm), n_D^{20} 1.4567, d_4^{20} 0.9101 [1].
*** Agreeing with [1] b.p. 126-128° (760 mm), n_D^{20} 1.4262, d_4^{20} 0.7515.
**** Agreeing with [7] b.p. 88-89°; agreeing with [8] d_4^{20} 1.0553, n_D^{20} 1.41409.

Found %: Ag 48.83; 48.79. $C_{12}H_{18}O_4Ag_2$. Calculated %: Ag 48.80.

2) 3,5,6,6-Tetramethyl-4-heptenic acid-1. The acid $C_{12}H_{20}O_4$(10 g) was decarboxylated at 150° (12 mm). The end of the reaction was determined by the end of the gas evolution. The monocarboxylic acid distilled at 198-199° (12 mm). 7.8 g (96.3%) was obtained.

n_D^{20} 1.4521, d_4^{20} 0.9069, MR_D 54.70; calc. 54.07.
Found %: C 72.65, 72.46; H 11.24, 11.13. $C_{11}H_{20}O_2$. Calculated %: C 71.69, 10.94.

The silver salt of the acid was obtained from an aqueous solution of its potassium salt.

Found %: Ag 36.95, 36.82. $C_{11}H_{19}O_2Ag$. Calculated %: Ag 37.07.

1.7 g of the acid $C_{11}H_{20}O_2$ was oxidized with 1% $KMnO_4$ solution. The reaction took place very rapidly with great evolution of heat. The oxidation products were steam distilled. The aqueous distillate was shown to contain pinacolone by the precipitation of the 2,4-dinitrophenylhydrazone melting at 125°, which remained unchanged after two recrystallizations.

SUMMARY

1. It has been shown that in the condensation of two molecules of a tertiary halide of the allylic type (2,2,3-trimethyl-3-chlorohexene-4) under the influence of magnesium, allylic rearrangement takes place with the formation of 2,2,3,5,6,8,9,9-octamethyldecadiene-3,7.

2. In the condensation of 2,2,3-trimethyl-3-chlorohexene-4 with the sodium derivative of malonic ester, preliminary isomerization of the halide takes place, leading to the formation of the diethyl ester of 3,5,6,6-tetramethyl-2-carboxy-4-heptenic acid-1. Hydrolysis of this ester and decarboxylation of the dicarboxylic acid formed leads to the formation of 3,5,6,6-tetramethyl-4-heptenic acid-1.

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** In Russian.

THE SYNTHESIS OF BRANCHED ACETYLENIC HYDROCARBONS

THE PREPARATION OF 2,6,6-TRIMETHYL-3,3-DIISOPROPYLHEPTYNE-4

A. I. Zakharova and G. M. Murashov

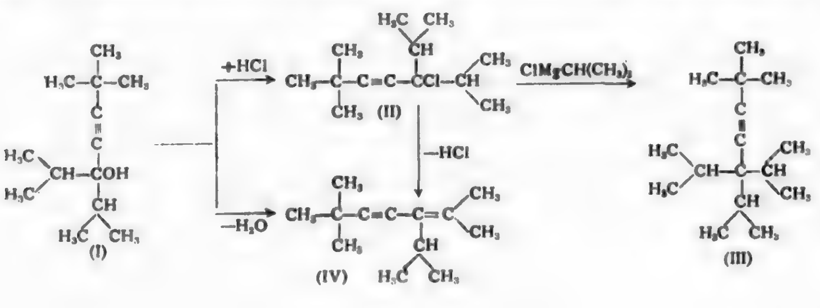
The present communication is a continuation of our studies in the field of the synthesis and examination of the properties of branched mono- and polyacetylenes with two or more quaternary carbon atoms in the molecule. It has been shown [1-3] that these hydrocarbons can be prepared by the propargylation of alkyl magnesium bromides or alkyne-1-yl magnesium bromides with tertiary acetylenic chlorides $R_2CCl-C\equiv C-R$ or ditertiary acetylenic dichlorides $R_2CCl-C\equiv C-CClR_2$.

The aim of the present work was the preparation and study of the properties of the branched acetylenic hydrocarbon—2,6,6-trimethyl-3,3-diisopropylheptyne-4(III) which contains two quaternary and three tertiary carbon atoms in the molecule. Particular interest is attached to this hydrocarbon by virtue of the fact that in it there are three tertiary carbon atoms attached to one quaternary carbon atom. As far as we are aware, no hydrocarbon of this type has been prepared up to the present, yet they may be of importance in the chemistry of motor fuels.

The starting material for the synthesis was the acetylenic tertiary alcohol first prepared by us—diisopropyl-tert-butylacetylenylcarbinol (I). The alcohol was prepared by the A. E. Favorsky reaction from tert-butylacetylene and diisopropyl ketone in the presence of powdered alkali (KOH) in ether. The tertiary acetylenic chloride—2,6,6-trimethyl-3-isopropyl-3-chloroheptyne-4 (II) was prepared for the first time by treating the carbinol (I) with gaseous hydrogen chloride according to the method used successfully by us several times [4].

The reaction between the chloride (II) and isopropyl magnesium chloride yielded the hydrocarbon (III) whose molecular weight and elementary analysis correspond to the formula $C_{16}H_{30}$. The hydrocarbon was shown to belong to the acetylene series by its Raman spectrum. The spectrum contains the intense frequency characteristic of the triple bond (2221.5 cm^{-1}). Calculation of the relative dispersion of hydrocarbon (III) showed in addition that it belongs to the class of hydrocarbons containing one multiple bond. The value of the relative dispersion was found to be 21.85 [5].

It should be noted that as a result of the presence of the unstable isopropyl radicals in all the compounds studied, the preparation of the carbinol (I), the conversion of the latter to the chloride (II) and the reaction of the chloride (II) with isopropyl magnesium chloride are to a large extent accompanied by dehydration of the carbinol or removal of hydrogen chloride from the chloride to form the enyne hydrocarbon—2,6,6-trimethyl-3-isopropylheptene-2-yne-4 (IV), whose structure has been proved by the appropriate analyses and by its Raman spectrum. The reactions described in the present communication may be represented by the following scheme:



EXPERIMENTAL

The preparation of diisopropyl-tert-butylacetylenylcarbinol (2,6,6-trimethyl-3'-metho-3-ethylheptyne-4-ol-3) (I). 150 g powdered caustic potash and 200 ml absolute ether were placed in a three-necked flask fitted with a rapid stirring propellor reflux condenser and dropping funnel. A mixture of 41 g (0.5 mole) tert-butylacetylene and 57 g (0.5 mole) diisopropyl ketone in 50 ml ether was added with external cooling to 0° and stirring over a period of 6 hours. After being stirred for 4 hours and then left to stand for 10 hours, the reaction mass was broken up with water with stirring and cooling. The ether layer was dried with ignited sodium sulfate, the ether distilled off, and the product remaining vacuum distilled. Two fractions were obtained: 1st – b.p. 58-65° at 7 mm, 10 g; 2nd – b.p. 65-76° at 5 mm, 74 g. The 1st fraction, after a second distillation, proved to be the enyne hydrocarbon (IV), described in detail below, while the 2nd fraction, after two vacuum distillations, proved to be the acetylenic carbinol (I) – a transparent glycerol-like viscous liquid with a camphor-like odor, yield 75%. The carbinol (I) is not described in the literature.

B.p. 75.5 at 5 mm, d_4^0 0.8506, d_4^{20} 0.8334, n_D^{20} 1.44142, n_C^{20} 1.43900, n_F^{20} 1.44743; MR_D 62.26, MR_C 61.97, MR_F 62.99. $C_{13}H_{24}O$ F. Calc. MR_D 61.95, MR_C 61.43, MR_F 62.49.

Found %: C 79.46, 79.78; H 12.12, 12.21. M 196.5, 194.9. $C_{13}H_{24}O$. Calculated %: C 79.53; H 12.32. M 196.3

The preparation of 2,6,6-trimethyl-3-isopropyl-3-chloroheptyne-4 (2,6,6-trimethyl-3'-metho-3-ethyl-3-chloroheptyne-4) (II). 53 g (0.27 mole) of the acetylenic hydrocarbon (I) (in portions of 5 g each) was treated with gaseous hydrogen chloride [4] and cooling. At first complete absorption of the gas took place, accompanied by a rise in temperature, after which the reaction mass gradually cooled and absorption of hydrogen chloride ceased. The substance was separated from water, dried over calcium chloride and vacuum distilled. Two fractions were obtained: 1st – b.p. 57-64° at 6 mm, 20 g; 2nd – b.p. 64-77° at 6 mm, 26 g. The 1st fraction yielded the enyne hydrocarbon (IV), described in detail below, while the 2nd fraction, after two vacuum distillations, yielded the acetylenic chloride (II) which is not described in the literature – a strongly refractive liquid, rapidly turning yellow in air (yield 45%).

B.p. 75.5 at 6 mm, d_4^0 0.9100, d_4^{20} 0.8943, n_D^{20} 1.47057.

Found %: Cl 16.42, 16.31. M 215.3, 212.9. $C_{13}H_{23}Cl$. Calculated %: Cl 16.51. M 214.8.

The preparation of 2,6,6-trimethyl-3,3-diisopropylheptyne-4 [2,6,6-trimethyl-di-(3'-metho-3-ethyl)-heptyne-4] (III). The Grignard reagent was prepared in the usual way from 6 g magnesium and 20 g isopropyl chloride in 125 ml absolute ether. 25 g of the chloride (II) in 50 ml ether was added to the organomagnesium compound with constant stirring and cooling with ice water over a period of two hours. The mixture was left for 12 hours, after which it was heated for 2 hours on the water bath at 40° and then decomposed with diluted hydrochloric acid and cooling. The ether solution was dried with ignited magnesium sulfate and the ether distilled off. After 4 vacuum distillations from metallic sodium (until a negative test for halide according to Beilstein) 23 g of a substance with b.p. 55-59° at 7 mm was obtained, whose Raman spectrum indicated the presence of double and triple bonds. This substance is evidently a mixture of the enyne hydrocarbon (IV) and the acetylenic hydrocarbon (III). The substance was again vacuum distilled, first from active charcoal, then from silica gel and finally by molecular distillation. 5.5 g (20%) of the acetylenic hydrocarbon (III) was separated, with the following constants:

B.p. 55° at 6 mm, d_4^0 0.8374, d_4^{20} 0.8208, n_D^{20} 1.45807, n_C^{20} 1.45513, n_F^{20} 1.46514, MR_D 73.95, MR_C 73.54, MR_F 74.93. $C_{16}H_{30}$ F. Calc. MR_D 74.02, MR_C 74.69, MR_F 74.96; ω_{FCD} 21.85.

Found %: C 86.12, 86.05; H 13.87, 13.92. M 219.7, 218.1. $C_{16}H_{30}$. Calculated %: C 86.40; H 13.60. M 222.4.

Raman spectrum of hydrocarbon (III). Taken on a glass spectrograph with a system of three prisms of constant divergence (ISP-51) (exciting line Hg_c 18308 cm^{-1}; reference lines: Hg_d 20336 cm^{-1}, Hg 16036 cm^{-1}). Glass light filter, yellow, width of slit 0.005 mm, exposure 24 hours. The intensity of the lines was estimated visually from a 5-division scale.

181.6(2), 286.6(1), 428.8(0.5), 555.2(0.5), 794.9(1), 904.7(3), 979.8(3), 104.22 (3), 1200.3(1), 1304.3(0.5), 1378.1(2), 1449.7(1), **2221.5**(5), 2924.8(3), 2973.5(4).

2,6,6-Trimethyl-3-isopropylheptene-2-yne-4(2,6,6-trimethyl-3'-metho-3-ethylheptene-2-yne-4)(IV) was obtained as a side-product in the synthesis of the carbinol (I), the chloride (II) and the hydrocarbon (III) as a result of dehydration or removal of hydrogen chloride. The hydrocarbon had the following constants (and is described for the first time).

B.p. 58.5° at 7 mm, d_4^0 0.7930, d_4^{20} 0.7778, n_D^{20} 1.45183, n_C^{20} 1.44887, n_F^{20} 1.46066, MR_D 61.82, MR_C 61.47, MR_F 62.86. $C_{13}H_{22}F|^{=}$. Calc. MR_D 59.70, MR_C 59.40, MR_F 60.55; ω_{FCD} 26.1.
Found %: C 87.29; H 12.70. M 177.3, 177.2. $C_{13}H_{22}$. Calculated %: C 87.56; H 12.44. M 178.3

Raman spectrum of hydrocarbon (IV) was taken on a glass spectrograph with a system of three prisms of constant divergence (ISP-51) (exciting line Hg 22938 cm^{-1}), glass filter, width of slit 0.007 mm, exposure 6 hours. The intensity of the lines was estimated visually from a 10-division scale.

179.8(8), 284.6(3), 361.7(1), 420.3(1), 452.9(5), 548.6(1), 639.8(1), 791.3(1), 902.7(4), 925.0(2), 1012.6(1), 1202.5(4), **1614.5**(10), **2220.9**(10), 2926.7(1), 2968.5(1).

SUMMARY

1. The tertiary acetylenic alcohol—diisopropyl-tert-butylacetylenyl carbinol (2,6,6-trimethyl-3'-metho-3-ethylheptyne-4-ol-3) (I) has been prepared and characterized for the first time by the condensation of tert-butylacetylene with diisopropyl ketone according to the method of A. E. Favorsky.

2. The chloride—2,6,6-trimethyl-3-isopropyl-3-chloroheptyne-4(2,6,6-trimethyl-3'-metho-3-ethyl-3-chloroheptyne-4 (II) has been prepared and characterized for the first time by the action of hydrogen chloride on the carbinol (I).

3. A new representative of the class of highly branched acetylenic hydrocarbons with two quaternary and three tertiary carbon atoms in the molecule—2,6,6-trimethyl-3,3-diisopropylheptyne-4(2,6,6-trimethyl-di-(3'-metho-3-ethyl)-heptyne-4)(III) has been prepared by the reaction of the chloride (II) with isopropyl magnesium chloride.

4. The vinylacetylenic hydrocarbon—2,6,6-trimethyl-3-isopropyl-heptene-2-yne-4(2,6,6-trimethyl-3'-metho-3-ethylheptene-2-yne-4)(IV) which is not described in the literature and is obtained by the dehydration of the carbinol (I) or by the removal of hydrogen chloride from the chloride (II), has been characterized.

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THE REACTION OF HYDROGEN SELENIDE WITH α-OXIDES OF THE ACETYLENE AND VINYLACETYLENE SERIES THE SYNTHESIS OF ALKYL-, HYDROXYALKYL- AND VINYLSELENOPHEN

F. Ya. Perveev, N. I. Kudryashova and D. N. Glebovsky

In a continuation of the study of the reaction of α-oxides of the acetylene and vinylacetylene series with nucleophilic reagents and of the possibility of cyclization of the products obtained, we have aimed at working out a new, sufficiently efficient method for preparing alkyl-, hydroxyalkyl- and vinylselenophens based on the α-oxides of the acetylene and vinylacetylene series. This research has been rendered necessary by the fact that the synthesis of vinyl- and hydroxyalkylselenophens has not been achieved up to the present.

Selenophen and alkylselenophens have been prepared up to the present by the following methods: by the action of phosphorus pentaselenide on γ-diketones [1], of acetylene [2] and diene hydrocarbons on metallic selenium [3], of hydrogen selenide on furan [4] and of selenium dioxide on alkanes [10]. In all cases the reaction was carried out at fairly high temperatures (200-500°) and the yield of selenophen and its homologs was comparatively low (up to 30%).

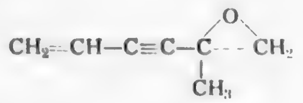
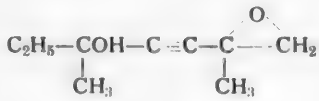
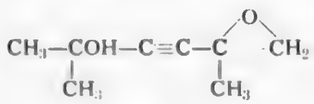
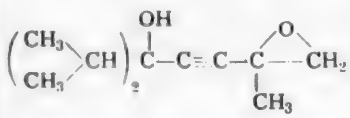
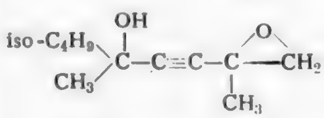
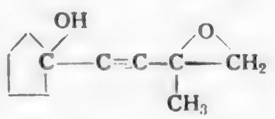
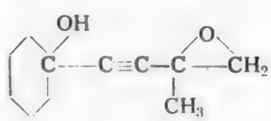
We have achieved the synthesis of homologs of selenophen by the action of hydrogen selenide on α-oxides of the acetylene and vinylacetylene series (Table 1) in the presence of barium hydroxide. The reaction of oxide (I) with hydrogen selenide yielded 2-ethyl-4-methylselenophen and 2-vinyl-4-methylselenophen. The oxide (II) with hydrogen selenide formed 2-(α-hydroxyisopropyl)-4-methylselenophen. Both hydroxy- and vinylselenophens were found in the products of the reaction of oxides (III-V). The vinylselenophens are formed as a result of dehydration of the corresponding hydroxycompounds. The oxides (VI) and (VII) give only unsaturated compounds in which the alcohol group cannot be detected even qualitatively.

All the products obtained are yellowish liquids with an unpleasant specific odor. They all give a characteristic coloration with isatin sulfate and form the corresponding mercury derivatives with mercury acetate. Prolonged working with the materials causes headache.

The synthesis of the selenophens was carried out in the following way: 100-150 ml water, 30-40 ml chloroform and 10-15 g barium hydroxide were placed in a round-bottomed flask fitted with mechanical stirrer. When the apparatus had been assembled, the air was displaced by nitrogen and hydrogen selenide passed in until the reaction mixture was saturated; the oxide was then added with slow passage of hydrogen selenide and vigorous stirring. At first the hydrogen selenide was observed to pass through but as the reaction proceeded it was absorbed completely. The temperature of the mixture was maintained at 30-40°. When the reaction was complete, acetic acid was added to the flask until the solid precipitates had dissolved completely. Nitrogen was then passed again through the system to remove traces of hydrogen selenide. The lower layer was removed and the reaction products steam distilled. When the final product desired was the unsaturated compounds, the distillation was carried out with the addition of small amounts of sulfuric acid or barium hydroxide. Further treatment of the products was carried out in the usual way.

2-Ethyl-4-methylselenophen (VIII) is formed if nitrogen is not passed through the system to begin with. In this case decomposition of the hydrogen selenide takes place and the hydrogen produced adds on to the double bond of the side chain of the vinylselenophen. When chloroform is not present in the reaction mixture, the reaction of hydrogen selenide with the oxides leads to the formation of a large amount of tarry products.

TABLE 1

No. of compound	Formula	Name
(I)		2-Methyl-1, 2-oxidohexene-5-yne-3
(III)		2,5-Dimethyl-1, 2-oxidoheptyne-3-ol-5
(II)		2,5-Dimethyl-1, 2-oxidohexyne-3-ol-5
(V)		2,6-Dimethyl-5-isopropyl-1, 2-oxidoheptyne- -3-ol-5
(IV)		2,5,7-Trimethyl-1, 2-oxidooctyne-3-ol-5
(VI)		2-Methyl-4-(1-hydroxycyclopentyl)-1, 2- -oxidobutyne-3
(VII)		2-Methyl-4-(1-hydroxycyclohexyl)-1,2- -oxidobutyne-3

The average yield of the selenophens varies from 30 to 80% and depends on the structure of the original oxides. With increase in length and degree of branching of the side chain the yield is decreased.

The selenophens are formed in greatest yield from the oxide containing alicyclic radicals. The constants of the compounds obtained are given in Table 2.

From the data given it may be taken as established that the reaction of hydrogen selenide with oxides of the acetylene and vinylacetylene series is a general reaction for the synthesis of vinyl-, alkyl- and hydroxyalkylselenophens.

The formation of selenophens from oxides on reaction with hydrogen selenide evidently takes place, as in the case of the thiophens, according to the following scheme [5-9]:

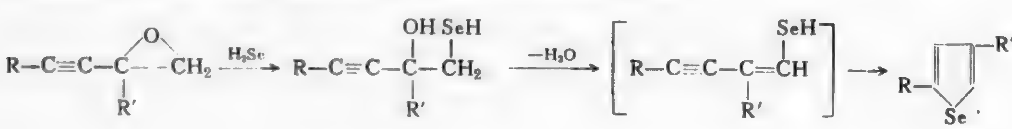
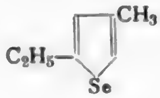
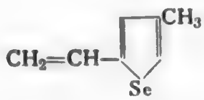
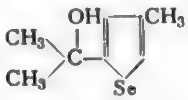
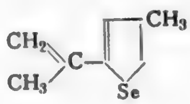
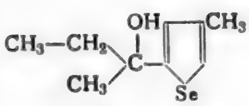
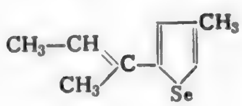
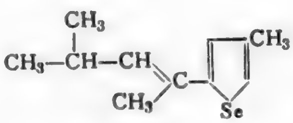
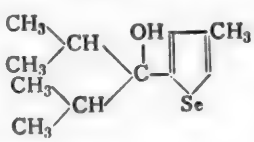
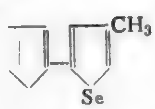
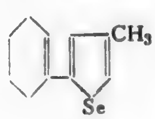


TABLE 2

Nò. of com-pound	Formula	Boiling point with pressure (mm)	n_D^{20}	d_4^{20}	MR_D Calc.	MR_D Found
(VIII)		29—30 (0.2)	1.5518	1.3069	42.0	42.34
(IX)		32 (0.5)	1.5900	1.3360	41.53	43.23
(X)		77—78 (0.5)	1.5530	1.3433	48.48	48.39
(XI)		72—73 (2)	1.5782	—	—	—
(XII)		73—74 (0.5)	1.5553	1.3000	53.63	53.70
(XIII)		61—62 (0.5)	1.5785	1.2740	51.08	51.88
(XIV)		77—78 (0.5)	1.5530	1.1847	60.65	61.37
(XV)		90—91 (0.8)	1.5310	1.2169	66.10	65.93
(XVI)		78—80 (0.5)	1.6052	1.3275	54.32	55.62
(XVII)		93 (1)	1.5960	1.2990	57.81	59.70

Proof of the structure of the compounds obtained was provided by infra-red spectroscopy.

EXPERIMENTAL

The preparation of 1-chloro-2,5,7-trimethyloctyne-3-diol-2,5. 0.5 mole methylisobutylacetylenylcarbinol, prepared according to Favorsky's method by the condensation of acetylene with methyl isobutyl ketone over powdered KOH, was added at room temperature with vigorous stirring to an ether solution of 1 mole ethyl magnesium bromide. When the carbinol had been added, the mixture was stirred for 1 hour and then 50 g chloroacetone was added. After several hours, the organomagnesium complex was decomposed with 30% acetic acid. The product was separated and treated in the usual way. A small amount of chlorohydrin was vacuum distilled and analyzed. B.p. 108° at 0.5 mm.

n_D^{20} 1.4790, d_4^{20} 1.0568, MR_D 58.69. $C_{11}H_{19}O_2Cl\overline{F}$. Calc. 58.92.
Found %: act. H 0.959, 0.954; Cl 17.38, 17.50. $C_{11}H_{19}O_2Cl$. Calculated %: act. H 0.986; Cl 17.49.

The preparation of 1-chloro-2,6-dimethyl-5-isopropylheptyne-3-diol-2,5. The chlorohydrin was prepared by the method of Iotsich from diisopropylacetylenylcarbinol and chloroacetone. Part of the chlorohydrin was vacuum distilled and analyzed. B.p. 114.5° at 1.5 mm.

n_D^{20} 1.4840, d_4^{20} 1.0601, MR_D 62.81. $C_{12}H_{21}O_2Cl\overline{F}$. Calc. 63.46.
Found %: act. H 0.840, 0.852; Cl 15.30, 15.41. $C_{12}H_{21}O_2Cl$. Calculated %: act. H 0.861; Cl 15.24.

The preparation of 2,5,7-trimethyl-1,2-oxidooctyne-3(IV). The oxide was obtained by the reaction of the glycol chlorohydrin with powdered KOH in anhydrous ether solution. B.p. 80-82° at 0.5 mm.

n_D^{20} 1.4611, d_4^{20} 0.9531, MR_D 52.45. $C_{11}H_{18}O_2\overline{F}$. Calc. 52.10.
Found %: act. H 0.596, 0.582; C 72.26, 72.30; H 9.94, 9.91. $C_{11}H_{18}O_2$. Calculated %: act. H 0.553; C 72.34; H 9.93.

The preparation of 2,6-dimethyl-5-isopropyl-1,2-oxidoheptyne-3-ol-5 (V). Obtained as in the previous case by the action of powdered caustic potash on the corresponding glycol chlorohydrin. B.p. 86° at 0.5 mm.

n_D^{20} 1.4668, d_4^{20} 0.9505, MR_D 57.28. $C_{12}H_{20}O_2\overline{F}$. Calc. 56.71.
Found %: act. H 0.537, 0.539; C 73.39, 73.36; H 10.25, 10.23. $C_{12}H_{20}O_2$. Calculated %: act. H 0.514; C 73.42; H 10.27.

The preparation of 2-ethyl-4-methylselenophen (VIII). 150 ml water and 10 g barium hydroxide were placed in a flask with reflux condenser, mechanical stirrer and dropping funnel. Hydrogen selenide was passed into the reaction mixture for 10 minutes. 23 g of oxide (I) was then added. The temperature of the reaction mixture rose to 60°. After this the hydrogen selenide was passed for a further 15 minutes and the color of the reaction mixture gradually changed to brown. Acetic acid was then poured into the reaction flask until the solid precipitates had dissolved completely. The material obtained was extracted with ether and dried over magnesium sulfate. The ether was distilled off and the substance vacuum distilled. Two fractions were obtained. The 1st fraction was redistilled after treatment with acidified water. 0.5 g of material was obtained whose constants corresponded to those of the material of the 2nd fraction. A glycol—the product of the hydration of the original oxide(I)—was found in the aqueous layer. The constants of the material of the 2nd fraction are given in Table 2 (VIII). Yield 6 g. When the oxide was added gradually the yield was markedly increased. Thus 30 g of oxide taken in a second experiment yielded 23 g of vinyl- and ethylselenophens with the latter predominating.

In this and all subsequent experiments the hydrogen selenide was prepared by decomposing 25 g aluminum selenide with water in a Wurtz flask, which was connected to the reaction vessel via a Tishchenko flask with chloroform. To avoid poisoning the whole flask was carefully washed with a concentrated solution of potassium permanganate after carrying out the experiment.

Found %: Se 45.47, 45.50. $C_7H_{10}Se$. Calculated %: Se 45.60.

The preparation of the mercury derivative of 2-ethyl-4-methyl-selenophen. 10 ml 33% sodium acetate solution and 50 ml cold saturated mercuric chloride solution were added to a solution of 1 g of selenophen (VIII) in 200 ml 95% alcohol. A flaky precipitate came down immediately. The solution was left overnight and then the precipitate was filtered off. 1.75 g of the chloromercury derivative was obtained. M.p. of product after recrystallization from 95% alcohol 117-118°.

Found %: Hg 48.87, 49.02. $C_7H_9ClHgSe$. Calculated %: Hg 49.15.

The preparation of 2-vinyl-4-methylselenophen (IX). The synthesis of the selenophen (IX) was carried out in the manner described above. In contrast to the previous method, however, dry nitrogen was passed through the system before and after the reaction. 25 ml chloroform was added to the reaction mixture. 20 g of oxide (I) in 25 ml chloroform was then added dropwise with the slow passage of hydrogen selenide. The temperature of the reaction mixture rose to 35° and was maintained by heating until the end of the reaction. The hydrogen selenide was passed for 4 hours. After addition of acetic acid the chloroform solution was separated and steam distilled. The substance was extracted with ether, dried over ignited magnesium sulfate, the ether distilled off, and the substance vacuum distilled. 15 g of selenophen (IX) was obtained. Yield 38%.

Found %: Se 46.05, 45.98. C_7H_8Se. Calculated %: Se 46.10.

The preparation of 2-(α-hydroxyisopropyl)-4-methylselenophen (X). This and all subsequent selenophens were obtained by the method described above. 10 g of oxide (II) was taken. 7.5 g of selenophen (X) was obtained. Yield 45%.

Found %: act. H 0.420, 0.412; Se 38.78, 38.90. $C_8H_{12}OSe$. Calculated %: act. H 0.496; Se 38.83.

The preparation of 2-isopropenyl-4-methylselenophen (XI). 5 g of hydroxyselenophen (X) was placed in 100 ml 5% sulfuric acid and steam distilled at constant volume of the reaction mass. The reaction product was extracted with ether and vacuum distilled. 4 g of substance (XI) was obtained.

Found %: Se 42.67, 42.65. $C_8H_{10}Se$. Calculated %: Se 42.66.

The preparation of 2-(α-hydroxyisobutyl)-4-methylselenophen (XII). 14 g of oxide (III) was taken and dissolved in twice its volume of chloroform. 13 g of selenophen (XII) with an admixture of the unsaturated compound (XIII) was obtained. After careful distillation 9 g of the hydroxyselenophen (XII) was obtained. Yield 45%.

Found %: act. H 0.394, 0.399; Se 35.99, 35.80. $C_9H_{14}OSe$. Calculated %: act. H 0.464; Se 36.36.

The preparation of 2-isobutenyl-4-methylselenophen (XIII). 4 g of the hydroxyselenophen (XII) was taken for the reaction. 3.5 g of (XIII) was obtained after dehydration by 5% sulfuric acid.

Found %: Se 39.50, 39.61. $C_9H_{12}Se$. Calculated %: Se 39.65.

The preparation of 2-(α, γ-dimethylbutenyl)-4-methylselenophen (XIV). 6.5 g of the hydroxy- and unsaturated selenophens were obtained from 10 g of the oxide (IV) by the reaction with hydrogen selenide. The mixture was dehydrated with 5% sulfuric acid. 5.2 g of the unsaturated compound (XIV) was obtained. Yield 40%.

Found %: Se 34.71, 34.90. $C_{11}H_{16}Se$. Calculated %: Se 34.75.

The preparation of 2-(α-hydroxy-α-isopropylisobutyl)-4-methylselenophen. The reaction of hydrogen selenide with the oxide (V) yielded 4.5 g of the hydroxyselenophen (XV). Yield 22%.

Found %: act. H 0.372, 0.388; Se 30.42, 30.39. $C_{12}H_{20}OSe$. Calculated %: act. H 0.389; Se 30.46.

The preparation of 2-cyclopentenyl-4-methylselenophen (XVI). 11 g of selenophen (XVI) was obtained from 10 g of oxide (VI) by the action of hydrogen selenide. No hydroxyselenophen was found in the reaction products. Yield 85%.

Found %: Se 37.32, 37.35. $C_{10}H_{12}Se$. Calculated %: Se 37.40.

The preparation of 2-cyclohexenyl-4-methylselenophen (XVII). The reaction of oxide (VII) with hydrogen selenide yielded 7.5 g of selenophen (XVII). Yield 60%.

Found %: Se 35.11, 35.09. $C_{11}H_{14}Se$. Calculated %: Se 35.06.

Analysis of the selenium was carried out by oxidizing the compound with concentrated nitric acid and subsequently reducing the selenic acid formed to selenious by prolonged boiling with concentrated hydrochloric acid. The solution was then diluted with water until the hydrogen chloride concentration was 6-8%. The selenious acid was reduced to metallic selenium with sodium sulfite and the selenium filtered off in a Shott filter.

SUMMARY

1. From a study of the reaction of hydrogen selenide with α-oxides of the acetylene and vinylacetylene series, a new general method has been worked out for the preparation of alkyl-, hydroxyalkyl- and vinylselenophens.

2. Ten new compounds not described in the literature have been prepared: 2-ethyl-4-methylselenophen, 2-vinyl-4-methylselenophen, 2-(α-hydroxyisopropyl)-4-methylselenophen, 2-isopropenyl-4-methylselenophen, 2-(α-hydroxyisobutyl)-4-methylselenophen, 2-isobutenyl-4-methylselenophen, 2-(α,γ-dimethylbutenyl)-4-methylselenophen, 2-(α-hydroxy-α-isopropyl-isobutyl)-4-methylselenophen, 2-cyclopentenyl-4-methylselenophen, 2-cyclohexenyl-4-methylselenophen.

3. It has been shown that the yield of products depends on the structure of the original oxides and is decreased as the chain length and its degree of branching increase.

4. It has been shown that increase in the length and degree of branching of the side chain of the selenophens increases the mobility of the hydroxyl group situated in the α-position to the selenophen ring. The greatest mobility is shown by the hydroxyl group of the selenophens with alicyclic radicals, which leads to the formation of only the corresponding unsaturated compounds.

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THE ADDITION OF POLYHALOGEN SILANES AND ALKYLHYDROSILANES TO COMPOUNDS CONTAINING A TRIPLE BOND

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Compounds of the type: $R_3SiC\equiv C-SiR_3$ and $R_3SiC\equiv CR_1$ were recently synthesized for the first time by ourselves [1] and by Frisch and Joung [2]. It has been shown [3] that the Si−C bond in these compounds is broken even under the mild conditions of hydration by Kucherov's method (as a result of the instability of compounds with a carbonyl group in the α-or the β-position), whereas it is very stable towards bromine, since either two or four atoms of bromine may be added across the triple bond.

The aim of the present work was to study the possibility of carrying out the addition of silicochloroform and methyldichlorosilane to compounds of the type $R_3SiC\equiv C-R$ in the presence of a catalyst. It turned out that $(CH_3)_3Si-C\equiv C-CH_3$ is capable of adding silicochloroform in the presence of benzoyl peroxide at 100°. Study of the reaction products has shown that the main fraction is the 1:1 adduct; besides this, however, the high-boiling 1:2 adduct is also present.

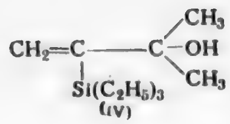
The adduct was methylated and from the Raman spectrum it was established that of the two forms (I) and (II), whose formation might be proposed, only form (II) was present, the formation of which is quite natural and is based on the distribution of charge signs on the original compounds.

$$\underset{\text{(I)}}{(CH_3)_3Si-CH=\underset{\displaystyle CH_3}{\underset{|}{C}}-Si(CH_3)_3} \qquad \underset{\text{(II)}}{(CH_3)_3Si-\underset{\displaystyle Si(CH_3)_3}{\underset{|}{C}}=CH-CH_3} \qquad \underset{\text{(III)}}{(CH_3)_3Si-\underset{\displaystyle Si(CH_3)_3}{\underset{|}{C}}=CH-C_6H_5}$$

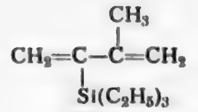
In the case of $(CH_3)_3SiC\equiv C-C_6H_5$ no addition of silicochloroform took place in the conditions described above. It proved possible to add methyldichlorosilane to this silicoacetylenic hydrocarbon and obtain the adduct (III) in good yield (85%), but only in different, more severe conditions (Pt/C catalyst at a temperature of 200-220°).

The nature of the addition of polyhalogen methanes to acetylenic hydrocarbons was studied by Kharasch [4]. He established that in the addition of $BrCCl_3$ to octyne-1 only the 1:1 adduct is obtained. In the case of octyne-2 and phenylacetylene, 1:1 and 1:2 adducts were formed (1 mol. polyhalogen methane and 2 mol. acetylenic hydrocarbon, forming a halogen-containing diolefin). There are very little data on the addition of silicon-containing compounds to acetylene and its derivatives [5]. Thus it is stated in a patent [6] that vinyltrichlorosilane is obtained by the addition of $HSiCl_3$ to acetylene over platinized asbestos.

With the aim of synthesizing silicon-containing compounds with isoprene radicals, we made a study of the addition of $(C_2H_5)_3SiH$ to dimethylacetylenylcarbinol over Pt/C catalyst, from which it was shown that at 160-180° only one product is obtained—α, α-dimethyl-β-triethyl-silylallyl alcohol (IV).

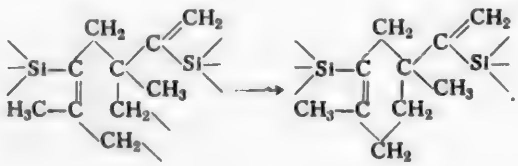


(IV)



(V)

Raising the temperature to 210-220° led to the formation of a 1:1 mixture of this alcohol and the cyclodimeric product of the dehydration of the alcohol according to the scheme:



The alcohol (IV) was dehydrated by distillation with $KHSO_4$, which led to the formation of 2-methyl-3-triethylsilylbutadiene (V). The latter compound polymerized easily in the presence of tert-butyl peroxide at 130°, even at atmospheric pressure, with the formation of a viscous oil with molecular weight approximately 9000. Under the same conditions at high pressure a rubber-like polymer was obtained.

EXPERIMENTAL

α-Trimethylsilyl-β-methylvinyltrimethylsilane (II). A test-tube containing 13.0 g trimethylsilylmethylacetylene (b.p. 98-99.5°, n_D^{20} 1.4180, d_4^{20} 0.7569), 2.8 g benzoyl peroxide and 60.0 g silicochloroform was placed in an autoclave. The autoclave was heated at 100° for 24 hours. The autoclave was cooled and its contents fractionated twice. Two fractions were isolated.

1st fraction b.p. 117.5-119° (49 mm), n_D^{20} 1.4783, d_4^{20} 1.1426, MR_D 61.41; calc. 61.48.
Found %: Cl 43.1, 43.2. $C_6H_{13}Si_2Cl_3$. Calculated %: Cl 42.95.
2nd fraction b.p. 167-170° (38 mm), n_D^{20} 1.5041, d_4^{20} 1.3530, MR_D 83.91; calc. 84.36.

Both fractions were treated separately in the usual way with methyl magnesium bromide, and the product broken up, extracted and fractionated to yield α-trimethylsilyl-β-methylvinyltrimethylsilane (II).

B.p. 172-173° (748 mm), n_D^{20} 1.4518, d_4^{20} 0.8026, MR_D 62.62; calc. 62.59.
Found %: C 58.12, 57.98; H 11.88, 12.04; Si 29.72, 29.74. $C_9H_{22}Si_2$. Calculated %: C 58.07; H 11.83; Si 30.10.

The following frequencies were found in the Raman spectrum (in cm^{-1}, intensity measured on a 10-division scale): 162(4 broad), 194(4 broad), 230(4), 270(5), 310(1), 396(6), 502(3), 618(3), 645(10), 688(5), 736(0), 762(0), 845(3), 1040(1), 1117(2), 1252(3), 1267(2), 1364(4), 1416(3), 1447(4), 1570(4), 2850(3), 2863(3), 2910(10), 2958(8 broad), 2970(4 broad).

The intense fully symmetrical (Si−C) frequency 645 cm^{-1} observed in the spectrum is considerably higher compared to the usual position in compounds of similar type, for example in $(CH_3)_3SiCH=C(CH_3)_2$ −615 cm^{-1}, in $(CH_3)_3SiCH=CH-CH_3$, 615 cm^{-1} and in $(CH_3)_3Si-CH=CHSi(CH_3)_3$, 610 cm^{-1} [7]. At the same time it coincides with the position of the analogous frequency in the spectrum of $(CH_3)_3Si-\underset{\displaystyle |\atop Si(CH_3)_3}{C}=CH_2$, at 646 cm^{-1} [8], which provides evidence for the formula given above.

α-Trimethylsilyl-β-phenylvinyltrimethylsilane (III). 13.5 g trimethylsilylphenylacetylene, 0.1 g Pt/C and 20 g methyldichlorosilane were placed in a test-tube and the mixture heated in an autoclave for 26 hours at 200-220°. The contents of the test-tube were then emptied out, the excess CH_3SiHCl_2 distilled off under atmospheric pressure, and the residue vacuum distilled in a current of dry air. 19.0 g of the addition product was isolated.

B.p. 144° (21 mm), $n_D^{20.5}$ 1.5204, $d_4^{20.5}$ 1.0693, MR_D 82.30; calc. 81.61.

The silicohydrocarbon prepared by treatment with excess methyl magnesium bromide had b.p. 146-147° (66 mm), n_D^{20} 1.5020, d_4^{20} 0.8775, MR_D 83.55; calc. 82.35.

Found %: C 68.74; H 9.64; Si 21.71. $C_{14}H_{24}Si_2$. Calculated %: C 67.74; H 9.6; Si 22.57.

Raman spectrum (cm^{-1}): 168(2), 191(7 broad), 225(4), 242(5), 318(4), 343(5), 450(6), 570(3), 605(3), 620(10), 695(5), 749(3 sharp), 771(1 broad), 845(4 broad), 900(4), 939(3 broad), 1000(10 sharp), 1030(6), 1076(0), 1124(1), 1153(4), 1174(7), 1218(5), 1250(4 broad), 1312(7), 1415(4 broad), 1447(3), 1553(6), 1576(4), 1603(10), 2845(4), 2897(10), 2962(9), 3055(9).

α, α-Dimethyl-β-triethylsilylallyl alcohol (IV). 10.0 g triethylsilane, 0.1 g Pt/C and 7.5 g dimethylacetylenylcarbinol were placed in a test-tube in an autoclave. The autoclave with aluminum cap was heated for 18-20 hours at 210-220°. Two fractions were isolated.

1st fraction b.p. 108-110° at 13 mm, 217-218° at 751 mm, n_D^{20} 1.4622, d_4^{20} 0.8628, MR_D 63.80; calc. 63.77.

Found %: C 66.03; H 12.02; Si 13.97; OH 0.93. $C_{11}H_{24}OSi$. Calculated %: C 66.00; H 12.00; Si 14.00; OH 1.

Raman spectrum (in cm^{-1}): 225(4), 400(0), 542(3), 585(6 broad), 638(1), 670(2), 726(2), 734(2), 772(5), 805(2), 912(0), 928(3 broad), 975(4), 1010(4 broad), 1022(3 broad), 1100(1), 1235(5 broad), 1318(6 broad), 1410(2), 1430(4 broad), 1465(6), 1626(5), 2815(2), 2880(10), 2910(8 sharp), 2954(5), 2960(5), 2970 (6 broad), 3065(2).

The intense frequency 772 cm^{-1}, which approximates in position the characteristic frequency of tert-butyl alcohol [9]—750 cm^{-1}, and the C—H frequency in the group = CH_2, 3065 cm^{-1}, may be noted. The value of the latter frequency is close to the corresponding frequencies observed in vinylsilanes, 3050-3055 cm^{-1} [7], while the frequency of the C=C bond—1626 cm^{-1}—is higher by ~30 cm^{-1} in comparison with the vinylsilanes (1594 cm^{-1}) [7], which is usually observed when a radical is added to the β-carbon atom of the C=C bond. The frequency of the hydroxyl group in the alcohol was not observed, probably on account of its low intensity.*

2nd fraction b.p. 205.5-206° at 9 mm, n_D^{20} 1.4954, d_4^{20} 0.8871, MR_D 119.97; calc. 120.18.
Found %: C 72.35; H 12.13; Si 15.48. $C_{22}H_{40}Si_2$. Calculated %: C 72.45; H 12.16; Si 15.40.

45 g of pure addition product (IV) was obtained by heating 25.5 g of the carbinol and 35.0 g of triethylsilane in the presence of 0.2 g Pt/C at 160-170° for 20 hours. No second fraction was found.

The dehydration of α, α-dimethyl-β-triethylsilylallyl alcohol (IV) over catalytic amounts of $KHSO_4$ led to the quantitative formation of 2-methyl-3-triethylsilylbutadiene-1,3 (V).

B.p. 91-91.5° at 14 mm, n_D^{20} 1.4715, d_4^{20} 0.8145, MR_D 62.13; calc. 61.75.
Found %: C 72.60, 72.47; H 12.04, 12.16; Si 15.13, 15.24. $C_{11}H_{22}Si$. Calculated %: C 72.50; H 12.08; Si 15.40.

Raman spectrum (in cm^{-1}): 488(5), 585(6 broad), 643(0), 725(1 broad), 803(2), 832(3), 890(3), 973(5), 1018(8), 1118(0), 1240(3 broad), 1313(10), 1380(4), 1417(4), 1470(4), 1571(8), 1623(20), 1660(3), 2881(9 double), 2909(6), 2955(6), 2995(3), 3080(5).

It is interesting to note that the intense frequencies of a compound of closely related structure, 2,3-

* The absorption spectrum shows the intense band of the OH-bond vibrations, consisting of two components, 3300-3450 and 3600 cm^{-1}, corresponding to "bound" and "free" hydroxyl.

-dimethylbutadiene (494, 1024, 1407, 1626, 3008, 3096 cm^{-1}[10]) are observed with a slight shift in our spectrum. The very intense frequency 1623 cm^{-1} is evidence of conjugated character of the multiple bonds.

SUMMARY

1. The addition of polyhalogen silanes ($HSiCl_3$ and CH_3HSiCl_2) to silicoacetylenic hydrocarbons of the type $R_3SiC \equiv CR$ has been achieved for the first time and the order of this addition has been established.

2. The addition of $(C_2H_5)_3SiH$ to dimethylacetylenylcarbinol has yielded α, α-dimethyl-β-triethylsilylallyl alcohol and dehydration of the latter has yielded 2-methyl-3-triethylsilylbutadiene and its cyclic dimer.

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TETRAACYLOXYSILANES IN ORGANIC SYNTHESIS

VIII. SILICOANHYDRIDES OF SATURATED MONOBASIC ORGANIC ACIDS IN THE SYNTHESIS OF KETONES OF THE THIOPHEN SERIES

Yu. K. Yuryev, G. B. Elyakov, N. S. Zefirov and A. N. Vysokosov

In previous works two of us have described a convenient method of acylating the thiophen nucleus using tetraacyloxysilanes—the silicoanhydrides of organic acids [1] and carrying out the reaction in the presence of anhydrous stannic chloride. The ease and simplicity of this synthesis of ketones of the thiophen and also of the selenophen series [2] should be noted, since in this acylation reaction we are practically using the organic acids themselves, which react with silicon tetrachloride to form the silicoanhydrides in good yield in the solvent used for the reaction. This avoids the necessity for preparing and separating the anhydride or the chloride of the acid in the pure state, which is extremely important in introducing the acyl radical of acids which are difficult to obtain.

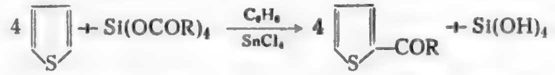
The high yields of ketones obtained earlier by acylation of the thiophen nucleus with the silicoanhydrides of saturated monobasic organic acids [1] led us to make a detailed study of this reaction and to establish the limits of its applicability.

In the present work acids with branched and complex radicals were used in the reaction described, which has enabled the influence of this factor on the yield of the corresponding 2-thienyl ketones to be established and several representatives of this class of compound not previously described to be prepared.

It turned out that with increasing length of the carbon atom chain in the organic acids and also with increased degree of branching of this chain, the yields of the 2-thienyl ketones are decreased. The influence of the first factor is the result for the most part of the greater complexity of separating the ketone obtained from the reaction mixture, which of course brings about a certain decrease in the yield. The influence of the second factor is due to a definite and sharp decrease in the yield of ketone. This can be seen from the examples given below of the preparation of ketones with isomeric alkyl radicals where the separation of the ketones from the reaction mixture was carried out in the same manner. Thus, n-butyl-2-thienyl ketone was obtained from thiophen and the silicoanhydride of n-valeric acid in yield 94% of the theoretical [1], while sec-butyl-2-thienyl ketone was obtained from thiophen and the silicoanhydride of methylethylacetic acid in 84% yield and tert-butyl-2-thienyl ketone from thiophen and the silicoanhydride of trimethylacetic acid in only 57% yield.

Even in the last example, however, the yield of ketone is fairly high, so that the value of the method described for acylating the thiophen nucleus is not reduced, and as a result of its simplicity it has undoubted advantages over methods in which the anhydrides or chlorides of the organic acids are used.

In the present work we have prepared the following ketones of the thiophen series by the acylation of thiophen with the silicoanhydrides of saturated monobasic organic acids: n-heptyl, n-nonyl, n-pentadecyl, sec-butyl, tert-butyl, cyclopentyl, cyclohexyl and α-naphthyl-2-thienyl ketones in yields of 53-84%.



(R = C_7H_{15}, C_9H_{19}, $C_{15}H_{31}$, sec. - C_4H_9, tert. - C_4H_9, C_5H_9, C_6H_{11}, α - $C_{10}H_7$).

EXPERIMENTAL

The synthesis of the ketones of the thiophen series was carried out by the method described by us earlier [1].

sec-Butyl-2-thienyl ketone. 20.8 g methylethylacetic acid, 24 g silicon tetrachloride and 16.8 g thiophen in the presence of 36 g anhydrous stannic chloride yielded 28.2 g (84%) of ketone.

B.p. 116° (12 mm), n_D^{20} 1.5370, d_4^{20} 1.0640, MR_D 49.03. $C_9H_{12}OSF_2$. Calc. 48.62.
Found %: C 64.59, 64.38; H 7.26, 7.23; S 18.97. $C_9H_{12}OS$. Calculated %: C 64.25; H 7.14; S 19.05.

sec-Butyl 2-thienyl ketone 2,4-dinitrophenylhydrazone—yellow plates: m.p. 127.3-127.4°.

Found %: N 16.55, 16.62. $C_{15}H_{16}O_4N_4S$. Calculated %: N 16.08.

tert-Butyl-2-thienyl ketone. 11 g trimethylacetic acid, 5 g silicon tetrachloride and 7 g thiophen in the presence of 12 g anhydrous stannic chloride yielded 7.6 g (57%) of the ketone.

B.p. 113-114° (14 mm), n_D^{20} 1.5363, d_4^{20} 1.0723, MR_D 48.70. $C_9H_{12}OSF_2$. Calc. 48.62.
Found %: C 64.39, 64.27; H 7.40, 7.26; S 18.98, 18.98. $C_9H_{12}OS$. Calculated %: C 64.25; H 7.14; S 19.05.

tert-Butyl-2-thienyl ketone semicarbazone—glistening white needles: m.p. 130.2-130.6°.

Found %: N 18.70, 18.71. $C_{10}H_{15}ON_3S$. Calculated %: N 18.66.

tert-Butyl-2-thienyl ketone 2,4-dinitrophenylhydrazone—orange-yellow crystals: m.p. 169°.

Found %: N 15.98, 15.95. $C_{15}H_{16}O_4N_4S$. Calculated %: N 16.08.

n-Heptyl-2-thienyl ketone. 14.4 g n-caprylic acid, 5 g silicon tetrachloride and 8.4 g thiophen in the presence of 14 g anhydrous stannic chloride yielded 14.2 g (70%) of the ketone.

B.p. 152-153° (8 mm), n_D^{20} 1.5192, d_4^{20} 1.0110, MR_D 63.16. $C_{12}H_{18}OSF_2$. Calc. 62.46.
Found %: S 15.36. $C_{12}H_{18}OS$. Calculated %: S 15.24.

2,4-Dinitrophenylhydrazone—bright yellow plates: m.p. 117°.

Found %: N 14.20, 14.40. $C_{18}H_{22}O_4N_4S$. Calculated %: N 14.35.

Literature data for n-heptyl-2-thienyl ketone: b.p. 140-143° (1 mm), n_D^{20} 1.5214 [2].

n-Nonyl-2-thienyl ketone. 20 g capric acid, 5 g silicon tetrachloride and 7 g thiophen in the presence of 12 g anhydrous stannic chloride yielded 12.5 g (63%) of the ketone.

B.p. 184° (9 mm), n_D^{20} 1.5138, d_4^{20} 0.9911, MR_D 71.55. $C_{14}H_{22}OSF_2$. Calc. 71.69.
Found %: S 13.55. $C_{14}H_{22}OS$. Calculated %: S 13.45.

Literature data for n-nonyl 2-thienyl ketone: b.p. 194° (17 mm), n_D^{20} 1.5089 [3].

n-Pentadecyl-2-thienyl ketone. 52 g of palmitic acid, 12 g silicon tetrachloride and 16.8 g thiophen in the presence of 26 g anhydrous stannic chloride yielded 39 g (60%) of the ketone.

B.p. 211° (4 mm), m.p. 36°.
Found %: C 74.32, 74.22; H 11.03, 10.83; S 10.02. $C_{20}H_{34}OS$. Calculated %: C 74.47; H 10.63; S 9.94.

n-Pentadecyl-2-thienyl ketone 2,4-dinitrophenylhydrazone—deep red crystals: m.p. 86°.

Found %: N 11.28, 11.50. $C_{26}H_{38}O_4N_4S$. Calculated %: N 11.14.

Cyclopentyl-2-thienyl ketone. 9.5 g cyclopentanecarboxylic acid, 5 g silicon tetrachloride and 7 g thiophen in the presence of 12 g anhydrous stannic chloride yielded 11.9 g (80%) of the ketone.

B.p. 128-129° (7 mm) n_D^{20} 1.5660, d_4^{20} 1.1378, MR_D 51.21. $C_{10}H_{12}OSF_2$. Calc. 51.03.
Found %: C 66.68, 66.75; H 6.82, 6.78; S 17.63. $C_{10}H_{12}OS$. Calculated %: C 66.61; H 6.71; S 17.78.

Cyclopentyl-2-thienyl ketone 2,4-dinitrophenylhydrazone—glistening yellow plates: m.p. 157°.

Found %: N 15.60, 15.64. $C_{16}H_{16}O_4N_4S$. Calculated %: N 15.54.

Cyclohexyl-2-thienyl ketone. 20 g cyclohexanecarboxylic acid, 15 g silicon tetrachloride and 12.6 g thiophen in the presence of 20 g anhydrous stannic chloride yielded 27.7 g (81.5%) of the ketone with m.p. 43-44°.

Found %: C 68.21, 68.38; H 7.33, 7.47; S 16.48. $C_{11}H_{14}OS$. Calculated %: C 67.98; H 7.26; S 16.50.

Cyclohexyl-2-thienyl ketone semicarbazone—glistening white plates: m.p. 152°.

Found %: N 17.93, 17.83. $C_{12}H_{17}ON_3S$. Calculated %: N 17.60.

α-Naphthyl-2-thienyl ketone. 14.4 g α-naphthoic acid, 5 g silicon tetrachloride and 7 g thiophen in the presence of 12 g anhydrous stannic chloride yielded 10 g (53%) of ketone: m.p. 69-70°.

Found %: C 75.66, 75.80; H 4.43, 4.27. $C_{15}H_{10}OS$. Calculated %: C 75.68; H 4.23.

Literature data for α-naphthyl-2-thienyl ketone: m.p. 68-69° [4].

SUMMARY

1. The use of the silicoanhydrides of saturated monobasic organic acids for the acylation of the thiophen nucleus enables acids with cycloparaffinic and branched radicals to be introduced.

2. The yields of ketones of the thiophen series using this method for their preparation is lowered with increased degree of branching of the hydrocarbon chains of the acid.

3. In the present work, n-heptyl, n-nonyl and α-naphthyl-2-thienyl ketones have been prepared using this method, together with the following ketones which are not described in the literature: sec-butyl, tert-butyl, n-pentadecyl, cyclopentyl, and cyclohexyl 2-thienyl ketones.

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STUDIES ON THE SYNTHESIS AND REACTIONS OF ORGANO-SILICON COMPOUNDS CONTAINING OXYGEN

THE SYNTHESIS OF DIALKYL-, ALKYLARYL- AND DIARYLSILANEDIOLS AND CERTAIN OF THEIR PROPERTIES

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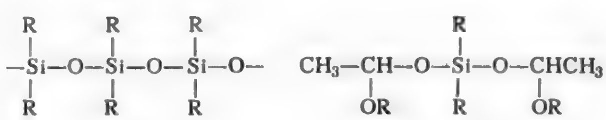
The present communication is a continuation of research on organosilicon compounds containing hydroxyl groups $R_nSi(OH)_{4-n}$, where n = 2 and 3. The work includes a description of the synthesis, properties and reactions of dialkyl(aryl)silanediols, i.e. compounds with the structure $R_2Si(OH)_2$, where R = H, CH_3, C_2H_5, C_6H_5, $C_{10}H_7$, etc.

Dialkyl(aryl)silanediols are very reactive and may be used as the starting materials for the preparation of a variety of organosilicon monomers and high-molecular compounds of technical importance.

Whereas the trialkyl(aryl)silanols R_3SiOH, in spite of their unique character, are analogous to the organic alcohols, as is confirmed in part by their reaction with vinyl ethers [1-3], the dialkyl(aryl)silanediols have no corresponding carbon analogs. Compounds $R_2C(OH)_2$ are unknown in carbon chemistry; only their derivatives exist.

When dialkyl(aryl)silanediols are heated, particularly in the presence of acids or alkalis, they condense readily with the formation of polysiloxanes of structure [1]. As our research has established, dialkyl(aryl)silanediols react with vinyl ethers with the formation of organosilicon diacetals with structure (II), where R = alkyl or aryl [4,6].



(I) (II)

Various organosilicon compounds may be used for the preparation of dialkyl(aryl)silanediols, including hydrogen-containing compounds of general structure R_nSiHX_{3-n}, where R = CH_3, C_2H_5, C_6H_5, and X = halide, OH, NH_2, SH, OR, OCOR, etc. Organosilicon compounds containing such reactive groups as multiple bonds: $CH_2{=}CH$[18], $CH{\equiv}C-$, etc. have similarly wide possibilities.

Alkyl(aryl)silanediols may be prepared by one of the following reactions:

$$1.\quad R_2SiX_2 + 2MeOH \rightarrow R_2Si(OH)_2 + 2MeX_2, \text{ where } R = C_2H_5,\ C_6H_5,\ C_{10}H_7,\ Me = K,\ Na, \text{ etc.}$$

$$2.\quad R_2Si(OCOR)_2 + 2HOH \rightarrow R_2Si(OH)_2 + 2RCOOH,$$

$$3.\quad RSiHCl_2 + 2HOH \rightarrow RSiH(OH)_2 + 2HCl,$$

$$4.\quad R_2Si(OR)_2 + 2HOH \rightarrow R_2Si(OH)_2 + 2ROH,$$

$$5.\quad R_2SiH_2 + 2NaOH \xrightarrow{ROH} R_2Si(OH)_2 + H_2.$$

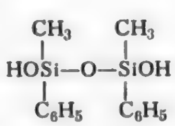
A comparison of the above methods has shown that the most general and convenient is the hydrolysis of the appropriate dialkyl(aryl)dichlorosilanes (equation 1) [7-11] or of the esters (equation 2).

The descriptions of the preparation and properties of dialkyl(aryl)silanediols given in the literature are insufficient and contradictory. For diphenylsilanediol, for example, the following different melting points are given: 128-132°[22], 131-132°[17, 25], 139°[5], 140°[23], 148°[24], 155°[15], etc. It has therefore proved useful to render more precise the methods for the preparation and the properties of dialkyl(aryl)silanediols and the lower products of their condensation. The preparation of methylphenylsiloxanediol and its derivative dimethyldiphenylsiloxanediol is not described in the literature at all. The preparation and properties of dinaphthylsilanediol is likewise described for the first time.

As has been established, several of the diols prepared: diethyl-, diphenyl-, ethylphenyl- and dinaphthylsilanediols, are stable compounds and may be stored out of contact with moisture. They undergo condensation, however, on prolonged storage or on heating.

The conditions of the hydrolysis of dialkyl(aryl)dihalogenosilanes have a distinct influence on the nature of the end products. If, for example, methylphenyldichlorosilane is hydrolyzed with water (in acid medium), the trimeric cyclic products with cis- and trans-structure are formed [14].

Certain workers have isolated compounds corresponding to the condensation of three and four molecules of silanediol from the products of the condensation of ethylphenyl-, benzylethyl- and diphenylsilanediols [10, 11]. If, however, the hydrolysis is carried out in dilute ether solution with aqueous alkali solutions, then, as we have observed, it is possible to isolate methylphenylsilanediol and dimethyldiphenylsiloxanediol



—the low-molecular product of its condensation—as individual compounds. When dialkyl(aryl)silanediols are heated for prolonged periods, particularly in the presence of materials capable of removing the elements of water, high-molecular polysiloxanes of very high molecular weight are formed.

On the basis of the above it is possible to establish definitely the stepwise (successive) condensation of the diols with the formation of intermediate dimeric, tetrameric etc. compounds, which leads to the formation of polysiloxanediols of the following structure:

$$6.\quad \mathrm{HO}\overset{R}{\underset{R}{\mathrm{Si}}}\mathrm{OH} + \mathrm{HO}\overset{R}{\underset{R}{\mathrm{Si}}}\mathrm{OH} \rightarrow \mathrm{HO}\overset{R}{\underset{R}{\mathrm{Si}}}\text{—O—}\overset{R}{\underset{R}{\mathrm{Si}}}\mathrm{OH} + H_2O,$$

$$7.\quad \mathrm{HO}\overset{R}{\underset{R}{\mathrm{Si}}}\text{—O—}\overset{R}{\underset{R}{\mathrm{Si}}}\mathrm{OH} + \mathrm{HO}\overset{R}{\underset{R}{\mathrm{Si}}}\mathrm{OH} \rightarrow \mathrm{HO}\overset{R}{\underset{R}{\mathrm{Si}}}\text{—O—}\overset{R}{\underset{R}{\mathrm{Si}}}\text{—O—}\overset{R}{\underset{R}{\mathrm{Si}}}\mathrm{OH}\ \text{etc.}$$

From this it follows that by changing the hydrolysis conditions it is possible to carry out the reaction to achieve the predominant formation of silanediols or of siloxanediols or of cyclopolysiloxanes.

With the aim of synthesizing hydrogen-containing alkylsilanediols, a study was made of the hydrolysis of ethyldichlorosilane $C_2H_5SiHCl_2$ with an aqueous solution of caustic potash or caustic soda under different conditions. The hydrolysis of hydrogen-containing alkyldichlorosilanes with aqueous alkali solutions is not described in the literature. In the hydrolysis of methyl- [19] and ethyldichlorosilane [20] in acid medium, only the methyl- and ethylcyclopolysiloxanes are formed, from which tri-, tetra- and pentacyclosiloxanes can be isolated. Together with the substances mentioned, the formation of some gel-like hydrolysis products was observed. We have examined the influence of the temperature, the concentration of the aqueous alkali solutions, and the nature and quantity of the solvent in the mixture being hydrolyzed. The experiments carried out have established that the hydrolysis of ethyldichlorosilane with aqueous solutions of caustic potash or caustic soda results in the formation of glassy, infusible, brittle high-molecular products, insoluble in ether, alcohol and benzene, instead of the silanediols expected. The analysis data and certain properties of the compounds obtained (insolubility, infusibility) lead to the postulation that the conditions indicated lead to the formation of highly condensed products with a three-dimensional structure. Their formation may be represented by the following equations:

$$8.\quad RSiHCl_2 + 2NaOH \rightarrow RSiH(OH)_2 + 2NaCl,$$

$$9.\quad RSiH(OH)_2 + NaOH \rightarrow \underset{\mathrm{ONa}}{\underset{|}{RSi(OH)_2}} + H_2,$$

$$10.\quad \underset{\mathrm{ONa}}{\underset{|}{RSi(OH)_2}} + HOH \rightarrow RSi(OH)_3 + NaOH,$$

$$11.\quad RSi(OH)_3 \xrightarrow{-H_2O} \begin{array}{ccccccc} & & R & & R & & \\ & & | & & | & & \\ \text{—O—} & & \mathrm{Si} & \text{—O—} & \mathrm{Si} & \text{—O—} & \\ & & | & & | & & \\ & & O & & O & & \\ & & | & & | & & \\ \text{—O—} & & \mathrm{Si} & \text{—O—} & \mathrm{Si} & \text{—O—}. & \\ & & | & & | & & \\ & & R & & R & & \end{array}$$

The first stage of the hydrolysis of alkyldichlorosilanes is the formation of alkylsilanediols, for example, $C_2H_5SiH(OH)_2$ (equation 8).

It is well known that trialkylsilanes R_3SiH, i.e. silicon compounds containing a mobile hydrogen atom,

are hydrolyzed in alcoholic alkali solution with the formation of trialkylsilanols. It is also known that the percentage content of Si—H bonds in organosilicon compounds may be determined from their reaction with concentrated alkalis [19]. In this way there is sufficient reason for supposing that the alkylsilanediols formed in the first stage are hydrolyzed further to alkylsilanetriols $RSi(OH)_3$. The formation from these of highly condensed compounds (equation 11) has been convincingly proved. We are suggesting that in the process of hydrolysis of ethyldichlorosilanes, intermediate alkylsilanolates $C_2H_5Si(OH)_2ONa$ are formed (equation 9), which undergo hydrolysis with the formation of alkylsilanetriols (equation 10).

In this way various products are formed, depending on the conditions of hydrolysis of alkyldichlorosilanes: in acid medium cyclic and linear polysiloxanes [19, 20] predominate, while in alkaline medium compounds with a three-dimensional (spatial) structure predominate. According to our suggestions, the gel-like hydrolysis products of unknown structure whose formation has been observed in aqueous medium (acid hydrolysis) by certain authors [19, 20] are also the products of further condensation of the cyclic polysiloxanes. In acid medium hydrolysis of the cyclic polysiloxanes is possible at the hydrogen atoms joined to the silicon.

The experiments carried out on the preparation of alkylsilanediols by the hydrolysis of $RSiHCl_2$, although they have not led to the isolation of the individual silanediols, have nevertheless indicated the possibility of their formation. This is also indicated by our experiments on the hydrolysis of dialkylchlorosilanes of structure R_2SiHCl, which have shown that the secondary silanols formed are readily converted into the disiloxanes (equations 12 and 13):

$$12.\quad R_2SiHCl + HOH \rightarrow R_2SiHOH + HCl,$$

$$13.\quad R_2SiHOH + HOSiHR_2 \xrightarrow{-H_2O} R_2SiH{-}O{-}SiHR_2 + H_2O.$$

Thus the high reactivity of compounds containing hydroxyl groups and hydrogen atoms in their structure and their tendency to form the siloxane linkage have been established.

Dialkyl(aryl)silanediols are crystalline substances, soluble in dioxane, ether, alcohol, etc. and insoluble in aliphatic solvents. Certain physicochemical characteristics of the chlorosilanes and the corresponding dialkyl(aryl)silanediols which have been prepared are given in Tables 1 and 2.

EXPERIMENTAL

1. The preparation of diethylsilanediol.* a) The hydrolysis of diethyldichlorosilane in alkaline medium. 32.0 g powdered caustic soda, 600 ml water and 100 g ethyl ether were placed in a three-necked flask fitted with reflux condenser, thermometer and dropping funnel. 60 g (0.3 mole) diethyldichlorosilane dissolved in 500 ml anhydrous ether was added with constant stirring and cooling of the reaction mass over a period of 15-20 minutes. During this time the temperature of the reaction mixture did not rise above +4°. The ether layer was then separated from the aqueous layer and the ether evaporated in a stream of dry air at room temperature to 0.1 of the initial volume. An equal volume of boiling isopentene was added and on cooling, the solution yielded a precipitate of white flaky crystals of diethylsilanediol (29.5 g, 65%), which after 3 recrystallizations from isopentene had m.p. 92-92.5°.

b) The hydrolysis of diethyldichlorosilane in neutral medium. 300 g of dry ether and several drops of phenolphthalein were placed in a four-necked flask cooled in a mixture of ice and salt and fitted with stirrer, thermometer and two stirring funnels. 1 N aqueous caustic soda or caustic potash solution was poured into one of the dropping funnels, and into the other—300 g ethyl ether and 40 g diethyldichlorosilane. The contents of both funnels were then added simultaneously with constant stirring to the flask over a period of 15-20 minutes,

* A. M. Gutman took part in the work.

TABLE 1

The Properties of Certain Dialkyl(aryl)dichlorosilanes

Spec. No.	Name of chloride	Formula	Boiling point (mm)	d_4^{20}	n_D^{20}	MR_D		Cl content (%)	
						Found	Calc.	Found	Calc.
1	Ethyldichlorosilane *	$C_2H_5SiHCl_2$	74.5° (752)	1.0849	1.4129	29.64	29.80	55.0	55.0
2	Diethyldichlorosilane*	$(C_2H_5)_2SiCl_2$	128—130 (756)	1.1050	1.4605	—	—	45.20 45.25	45.15
3	Methylphenyldichlorosilane	$(CH_3)(C_6H_5)SiCl_2$	198—200 (741)	1.1604	1.5180	49.75	49.36	37.21 37.00	37.12
4	Ethylphenyldichlorosilane	$(C_2H_5)(C_6H_5)SiCl_2$	227—230 (750)	1.1837	1.5321	53.70	53.99	33.34 33.84	34.57
5	Diphenyldichlorosilane	$(C_6H_5)_2SiCl_2$	298—302 (756) 163—165 (10)	1.186	—	—	—	28.0 27.95	28.01
6	Dinaphthyldichlorosilane**	$(C_{10}H_7)_2SiCl_2$	230—235 (3)***	—	—	—	—	—	—

* Separated by fractionation of the products of the direct synthesis of the ethylchlorosilanes by the interaction of ethyl chloride and a contact mass of copper and silicon [12].

** Prepared for the first time. Synthesized from naphthyllithium and silicon tetrachloride.

*** M.p. 151-152°.

TABLE 2

The Properties of Certain Dialkyl(aryl)silanediols

Spec. No.	Name of diol	Formula	Melting point	Analysis results (%)						Mol. wt. ****	
				C		H		Si			
				Found	Calc.	Found	Calc.	Found	Calc.	Found	Calc.
1	Diethylsilane-diol*	$(C_2H_5)_2Si(OH)_2$	92.0—92.5°	40.45, 40.32	40.00	10.14, 10.07	10.00	23.74, 23.62	22.38	114.6, 109.3	120.18
2	Diphenyl-silanediol**	$(C_6H_5)_2Si(OH)_2$	139.0	66.70, 66.61	66.62	5.52, 5.56	5.59	13.19, 12.33	12.95	211.5, 210.7	216.27
3	Methylphenyl-silanediol	$(CH_3)(C_6H_5)Si(OH)_2$	74—75	54.72, 54.90	54.55	6.51, 6.62	6.43	17.63, 17.69	18.20	158.10, 165.12	154.0
4	Ethylphenyl-silanediol***	$(C_2H_5)(C_6H_5)Si(OH)_2$	68.5	57.07, 57.25	57.19	7.32, 7.27	7.73	16.92, 16.74	16.70	145.3, 150.0	168.0
5	Dimethyldiphenyl-siloxanediol	$HOSi(CH_3)(C_6H_5)-O-Si(CH_3)(C_6H_5)OH$	113.0	57.29, 57.39	57.92	6.03, 6.15	6.24	19.24, 18.88	19.33	301.0, 300.0	290.40
6	Dinaphthyl-silanediol	$(C_{10}H_7)_2Si(OH)_2$	157—158	75.81, 75.14, 74.87	75.93	5.33, 5.54, 5.04	5.10	7.53, 7.89, 8.55	8.87	—	—

* Literature data: m.p. 100° [13]; 96° [9].

** Literature data: m.p. 138-139° [5]; 131-132° [17].

*** Literature data: m.p. 70° [10].

**** Molecular weight determined in dioxane. The dioxane was prepared for the analysis according to [21].

keeping the medium neutral. The temperature of the reaction mixture did not rise above +4°. The subsequent separation of the diethylsilanediol was carried out as described above. In these conditions the diethylsilanediol was obtained in yield up to 75%.

The diethylsilanediol had the form of white scaly crystals with a camphor-like odor. The diethylsilanediol liquefied on prolonged heating above 60°. It may be kept for a prolonged period out of contact with moisture.

2. The hydrolysis of ethyldichlorosilane. The reaction was carried out in the apparatus and according to the method described above. 37.2 g caustic soda (0.93 mole), 600 ml water and 100 ml ethyl ether were taken for the hydrolysis; a mixture of 60 g (0.46 mole) ethyldichlorosilane and 500 g anhydrous ether was then added with constant stirring from a dropping funnel over a period of 15-20 minutes. During this time the temperature of the reaction mixture did not rise above 3-5°. When the ether layer had been separated, washed with several portions of water and the ether distilled off in vacuo, a transparent gel was left, which changed after several hours into a solid glassy material which decomposed on heating above 400°. It was insoluble in ether, alcohol and benzene but swelled in these solvents. Samples of the material before analysis were broken up, washed with several portions of water (to remove possible traces of alkali), alcohol, ether, benzene and then again with water, after which they were dried in vacuo to constant weight.

Found %: C 29.23, 29.20; H 6.31, 6.56; Si 34.30, 35.32. $C_2H_5SiO_{1.5}$. Calculated %: C 29.60; H 6.18; Si 34.64.

In agreement with the analysis data, the infusibility and insolubility of the compound obtained correspond to highly condensed products with a three-dimensional structure.

3. The preparation of diphenylsilanediol. 1 N caustic soda (or caustic potash) was added from a dropping funnel with constant stirring to a mixture of 63.3 g (0.25 mole) diphenyldichlorosilane, 300 ml dry ether and several drops of phenolphthalein until a permanent pink coloration appeared. The temperature of the reaction mass should not exceed +5°. The ether layer was then separated from the aqueous layer and the ether vacuum distilled to 0.1 of the volume. During this operation needle-like crystals of diphenylsilanediol started to precipitate, and after complete precipitation with isopentane and two recrystallizations from an ether-isopentane mixture the crystals had m.p. 139°. Yield of diphenylsilanediol – 46.7 g (36.5%). The best method for the recrystallization of diphenylsilanediol proved to be the addition of boiling isopentane to a concentrated ether solution of the diphenylsilanediol.* Diphenylsilanediol is soluble in ether, slightly soluble in alcohol, vinyl butyl ether, soluble with difficulty in water. On heating, the solubility in benzene, toluene and isopentane is increased.

4. The preparation of methylphenylsilanediol and dimethyldiphenylsiloxanediol. 38.2 g methylphenyldichlorosilane dissolved in 500 ml dry ether was taken for hydrolysis. The reaction was carried out according to the method described above (experiment 1). The temperature of the reaction medium should not exceed +1°. The crystalline reaction products consisted of two fractions: one soluble in water and one insoluble. The water-soluble compound was extracted after treating the aqueous solution of the crystalline reaction products with ether, and after recrystallization from a cooled ether-isopentane mixture it corresponded, according to the analysis data, to methylphenylsilanediol (m.p. 74-75°) (Table 2). The yield amounted to 0.3 g (1%). The substance which was insoluble in water was recrystallized from a slightly heated mixture of isopentane and benzene and had m.p. 112-113°. Yield 12.4 g (40.3%). From the analysis data it proved to be dimethyldiphenylsiloxanediol.

It should be noted that prolonged and repeated recrystallization of the products of the hydrolysis of methylphenyldichlorosilane leads to the further condensation of the silanediols. In this process the formation of methylphenylsiloxanediol with higher melting point and molecular weight is observed.

5. The preparation of α-dinaphthylsilanediol. a) The synthesis of α-dinaphthyldichlorosilane. 250 ml

* Recrystallization of diphenylsilanediol from an aqueous acetone solution [17] had little success.

dry benzene was poured into a flask fitted with reflux condenser, dropping funnel, thermometer and mechanical stirrer, the air was displaced with nitrogen (all subsequent operations with organolithium compounds were carried out in an atmosphere of nitrogen), a mixture of 162 g naphthyllithium and 200 ml benzene was added followed by 95.5 g $SiCl_4$ added with stirring from a dropping funnel over a period of 2 hours at 18-20°. When the $SiCl_4$ had been added the temperature of the reaction mixture was raised to 50-60° over a period of 1 hour and the mixture heated for a further 2 hours. The reaction mass was cooled, the crystalline precipitate which formed was filtered off and washed with water, and the benzene distilled from the filtrate in vacuo (at 100-120 mm). The residue obtained was washed twice with isopentane and crystallized from a mixture of heptane and benzene. The main product from this had m.p. 151-152°, b.p. 230-235° (3 mm).

Found %: C 68.23, 68.27; H 4.03, 3.98; Si 8.28, 8.18; Cl 19.58. $C_{20}H_{14}Cl_2Si$. Calculated %: C 67.98; H 3.99; Si 7.93; Cl 20.06.

The substance isolated was α-dinaphthyldichlorosilane; readily soluble in benzene and hot heptane, sparingly soluble in isopentane.

b) The hydrolysis of α-dinaphthyldichlorosilane. α-Dinaphthylsilanediol was prepared from α-dinaphthyldichlorosilane by the method described above for the hydrolysis of diethyldichlorosilane in neutral medium, but in this case the hydrolysis was carried out for 1.5-2 hours instead of 15-20 minutes. When the ether extracts had been separated and the ether distilled off, crystals of the silanediol formed and were recrystallized from benzene and heptane, washed with isopentane and dried in vacuo (1-2 mm). M.p. 157-158°.

Found %: C 75.81, 75.14; H 5.33, 5.54; Si 7.53, 7.89, 8.55. M 313.5, 323.7. $C_{20}H_{16}O_2Si$. Calculated %: C 75.93; H 5.10; Si 8.87. M 316.3.

α-Dinaphthylsilanediol is readily soluble in ether, soluble on heating in benzene. It dissolves very sparingly in aliphatic hydrocarbons.

SUMMARY

1. A study of the literature data and the research carried out has shown that a general and extremely convenient method for the preparation of dialkyl(aryl)silanediols is provided by the hydrolysis of dialkyl(aryl) dichlorosilanes by aqueous alkali solutions, keeping the medium neutral. Diethyl-, ethylphenyl-, diphenyl-, methylphenyl- and dinaphthylsilanediols have been prepared by this method. Methylphenylsilane-, dinaphthylsilane-, dimethyldiphenylsiloxanediols and also dinaphthyldichlorosilane have been prepared for the first time.

2. The hydrolysis of methylphenyldichlorosilane has yielded, in addition to methylphenylsilanediol, a lower product of its condensation—dimethyldiphenylsiloxanediol, which confirms the stepwise nature of the formation of the polysiloxanediols.

3. It has been shown that the hydrolysis of hydrogen-containing alkyldichlorosilanes in alkaline medium leads to the formation of highly condensed products which apparently have a three-dimensional structure. A mechanism for the formation of the latter has been suggested.

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THE REACTION OF VINYL ETHERS WITH COMPOUNDS CONTAINING MOBILE HYDROGEN

I. THE REACTION OF VINYL BUTYL ETHER WITH ESTERS OF MALONIC ACID

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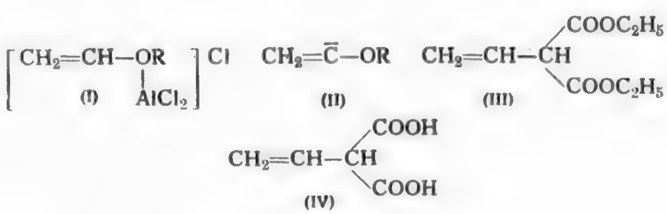
M. F. Shostakovsky and coworkers [1] have described a reaction for the preparation of acetals based on vinyl ethers. In a number of works by these authors it has been established that in reaction with vinyl ethers the mobile hydrogen atom of the carboxyl group adds on to the ruptured bond of the vinyl group according to Markovnikov's rule. In this case, as in the case of the preparation of acetals [2], new compounds are formed with the same oxygen-carbon bond at the one reaction center—the double bond. In contrast to this, the compounds in which a new C—C-bond is formed in reactions of this type have been comparatively little studied. It has therefore seemed of interest to us to study the reactions of vinyl ethers with the esters of dicarboxylic acids containing mobile hydrogen atoms, in particular, the esters of malonic and acetoacetic acids. The formation of compounds with a carbon-carbon bond may take place either at the double bond or at the ether link.

The starting materials for the reaction were vinyl butyl ether and malonic ester. The reaction was carried out in the presence of a catalyst, since under ordinary conditions it takes place very slowly. The catalyst used by us was anhydrous aluminum chloride, which has already been used for the condensation of vinyl ethers with aromatic hydrocarbons [3]. In our case it might have been expected that the main reaction would be the addition reaction, as a result of which the end product would have been hydroxybutyric acid. The experiments carried out showed, however, that the main reaction product was the ethyl ester of vinylmalonic acid. The reaction mechanism may be hypothetically represented by the formation of a series of intermediate products. Taking the ionic properties of the oxygen atom in vinyl butyl ether into consideration, in accordance with the literature data [4,5], we may postulate the formation of the oxonium compound (I), which decomposes further with the formation of the activated unstable molecule, or rather ion (II).



The reaction of this activated molecule with malonic ester leads to the formation of the ethyl ester of vinylmalonic acid (III), which on hydrolysis gives vinylmalonic acid (this acid was found in small amount even in the treatment of the reaction products—as a result of secondary processes). The vinylmalonic acid was converted to vinylacetic acid by decarboxylation.

EXPERIMENTAL

After careful purification, the original vinyl butyl ether, prepared according to the method of [6], had constants agreeing with those in the literature. The malonic ester, prepared by the generally adopted method from monochloroacetic acid, was repeatedly purified until its constants agreed with those given in the literature. Chemically pure anhydrous aluminum chloride with $AlCl_3$ content 98.5% was used. The reaction was carried out in a three-necked flask with mercury seal and reflux condenser protected from atmospheric moisture with a calcium chloride tube. 20 g (0.2 mole) vinyl butyl ether and 32 g (0.2 mole) malonic ester were taken for the reaction. The catalyst was added after the reaction mixture had reached room temperature. When the catalyst was added the temperature of the mixture rose sharply. The reaction was carried out at 28-30° for 4-5 hours. 6.5 g (0.05 mole) of aluminum chloride was added (in small portions). The reaction mixture was left overnight at room temperature to complete the reaction. The reaction products were isolated by treating the mixture obtained in the usual way employed in the Friedel-Crafts synthesis. The liquid obtained was fractionated in vacuo, the main reaction product being isolated as a fraction with b.p. 172-174° (75 mm), weight 12.3 g (38.91%).

n_D^{20} 1.4378, d_4^{20} 1.0430, MR_D 46.53; calc. 46.50.
Found %: C 57.88; H 4.72. M 182.2, 184. $C_9H_{14}O_4$. Calculated %: C 58.06; H 4.839. M 186.

The properties of the compound obtained showed it to be the ethyl ester of vinylmalonic acid. On hydrolysis of the ester a fraction with b.p. 147-149° (75 mm) was isolated.

n_D^{20} 1.4270, d_4^{20} 1.0425, MR_D 32.90; calc. 29.33
Found %: C 46.17; H 4.570. M 129.4, 131. $C_5H_6O_4$. Calculated %: C 46.16; H 4.616. M 130.

The vinylmalonic acid was decarboxylated, as a result of which a compound with b.p. 162-164°, d_4^{20} 1.0132, n_D^{20} 1.4256, was isolated. These data correspond to those of vinylacetic acid.

We express our deep gratitude to M. F. Shostakovsky for his interest and the valuable advice given while this work was being carried out.

SUMMARY

1. It has been established that in the reaction of vinyl butyl ether with malonic ester in the presence of aluminum chloride the main product of the reaction is the ethyl ester of vinylmalonic ester, which has not been described in the literature before.

2. The products of partial hydrolysis and the preparation of vinylacetic acid by decarboxylation confirm that the most reactive center in the conditions described is the butoxy group, as a result of which the substitution reaction takes place. The product of addition to the vinyl group was not isolated even in traces under the conditions described.

3. A hypothetical mechanism for the formation of the reaction products described above is presented.

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REACTIONS OF CERTAIN β,β-DIHALOGEN SUBSTITUTED PROPIONALDEHYDES

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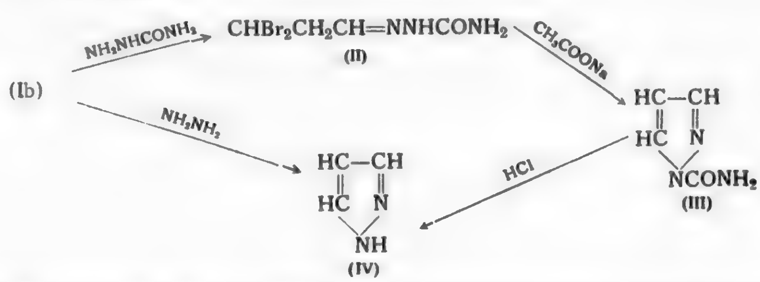
β,β-Dihalogen substituted propionaldehydes and their derivatives are of interest as a result of the fact that these compounds, whose structures are close to that of the dialdehyde of malonic acid, may resemble the latter in their reactions also. As is known, the dialdehyde of malonic acid is at the present time a very difficult compound to obtain, in spite of the fact that it is of very great interest as the first member of the series of β-dicarbonyl compounds which play such an essential part in synthetic chemistry. It may be supposed that β,β-dihalogen substituted propionaldehydes or their derivatives are also capable, under certain conditions, of acting as materials for the introduction into the molecules of various substances of the important hydrocarbon link $-CH=CH-CH=$, with the formation of aliphatic or cyclic compounds containing conjugated double bonds. The compounds used at the present time for this purpose, in addition to the dialdehyde of malonic acid [1], include β-ethoxyacroleindiethylacetal [2,3] and the acetal of propargylaldehyde [4].

The β,β-dihalogen substituted propionaldehydes have been little studied. Only recently a compound of this type has been prepared by the radical addition, initiated by acetyl peroxide, of bromodichloromethane to vinyl acetate, the resultant compound being 1,1-dichloro-3-bromo-3-acetoxypropane (Ia) [5-7], which is a functional derivative of β,β-dichloropropionaldehyde

$$CHX_2CH_2CHBr(OCOCH_3)$$

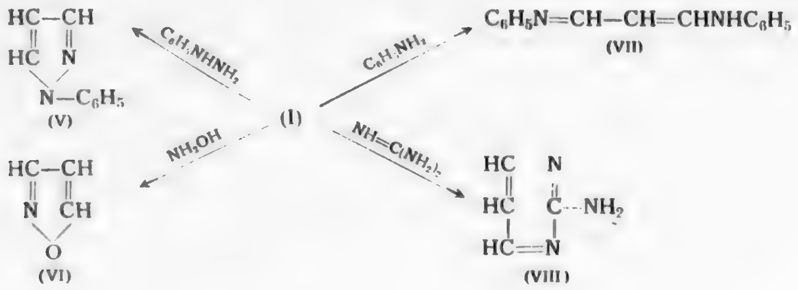
(I) a) X = Cl, b) X = Br

In the present work the synthesis of 1,1,3-tribromo-3-acetoxypropane (Ib) is described, and a study is made of certain of the reactions of this compound, and also of the compound (Ia) mentioned above, leading for the most part to the formation of the simplest heterocyclic compounds. (Ib) was obtained by heating a mixture of bromoform and vinyl acetate in the molar ratio of 2.5:1 in the presence of a catalytic amount of benzoyl peroxide. When heated with semicarbazide hydrochloride in mild conditions (Ib) forms the unstable semicarbazone of β,β-dibromopropionaldehyde (II), which is cyclized on heating with sodium acetate solution into the amide of pyrazole-1-carboxylic acid (III); the structure of the latter is proved by the fact that on hydrolysis and decarboxylation it is converted into pyrazole (IV), which is also obtained in 55-65% yield by the direct reaction of (Ia) or (Ib) with hydrazine.*



* In this case, and also in the reactions of compound (I) with phenylhydrazine or hydroxylamine, described below, the intermediate hydrazones or oximes of (I) could not be isolated.

The reaction of (I) with phenylhydrazine leads to the formation of 1-phenylpyrazole (V) in approximately 60% yield.



The reaction of (I) with hydroxylamine leads to the formation, in 30-40% yield, of isoxazole (VI) which is identified as the double salt with cadmium chloride.

Although the reactions mentioned above proceed with satisfactory results when agents which combine with acids are introduced into the reaction medium, the presence of the latter is not essential, and the same reactions may be carried out by heating the components in alcoholic or aqueous-alcohol solution. The preparation of 2-aminopyrimidine (VIII) by the reaction of (I) with guanidine salts is likewise best achieved by saturating an alcohol solution of the reagents with hydrogen chloride.* From these data it may be suggested that the reaction takes place via the intermediate stages of the formation of: a) the free β, β-dihalogen substituted propionaldehyde, b) its aldehyde derivative and c) the β-halogen substituted acrolein derivative with possible cyclization of the last of these. The direction of the reaction is determined by the possibility of formation of a stable system of conjugated double bonds.

EXPERIMENTAL

1,1,3-Tribromo-3-acetoxypropane (Ib). 13.8 g (0.16 mole) of freshly-distilled vinyl acetate and a solution of 1.3 g benzoyl peroxide in 20 g (0.08 mole) of bromoform were added simultaneously with stirring over a period of one hour to 81 g (0.32 mole) of freshly-distilled bromoform heated to 65°, after which the mixture was heated for 3 hours at 70-75°. The unreacted bromoform and vinyl acetate were vacuum distilled at 35-40 mm (51 g of mixture was recovered). The residue was fractionated at 2 mm. 20.3 g (37%, calculated from the vinyl acetate taken) of 1,1,3-tribromo-3-acetoxypropane with b.p. 98-102° (2 mm) was obtained. Pale yellow liquid, immiscible with water, soluble in alcohol and ether, unstable on storage. For the analysis, the substance was distilled a second time, the fraction with b.p. 98-98.5° (2 mm) being taken.

d_4^{20} 2.0946, n_D^{20} 1.5365, MR_D 50.44; calc. 50.24.

Found %: Br (total) 70.42, 70.55; Br (ionic) 23.65, 24.10. $C_5H_7O_2Br_3$. Calculated %: Br (total) 70.70; Br (ionic) 23.57.

β,β-Dibromopropionaldehyde semicarbazone (II). A solution of 1.5 g (0.013 mole) of semicarbazide hydrochloride in 5 ml water was added to a solution of 4.07 g (0.012 mole) of (Ib) in 32 ml ethyl alcohol, after which a solution of 4.08 g (0.03 mole) of sodium acetate in 5 ml water was added gradually with stirring. The crystals which had precipitated after standing for 2 hours at room temperature were filtered off. 1.4 g (43%) of semicarbazone, m.p. 125-126° (with decomp.) was obtained. A further 1.3 g of less pure material was obtained by evaporation of the alcohol from the mother liquor in vacuo. The semicarbazone changed rapidly

* It is indicated in the patent literature that a similar reaction may be carried out in concentrated sulfuric acid [8].

on storage.

Found %: N 15.39, 15.29. $C_4H_7ON_3Br_2$. Calculated %: N 15.38.

The amide of pyrazole-1-carboxylic acid (III). 1.8 g (0.013 mole) of crystalline sodium acetate was added to a solution of 1.4 g (0.005 mole) of (II) in 30 ml 50% ethyl alcohol and the mixture boiled for 1.5 hours. When the solution had stood for a short time, 0.55 g (96%) of yellowish crystals precipitated, m.p. 131-135° (with decomp.); after recrystallization from water (III), m.p. 135-137°. Literature data [2]: m.p. 136.5°.

Pyrazole (IV). a) From the amide of pyrazole-1-carboxylic acid. 2.5 ml 20% hydrochloric acid was added to 0.5 g of (III) and the mixture heated at the boil for 1.5 hours. The pale yellow solution obtained was made alkaline with 20% caustic soda solution, extracted several times with ether and the ether solution dried with potassium carbonate. The ether was evaporated,leaving 0.2 g of pale yellowish crystals of pyrazole, which after vacuum distillation had m.p. 69-70°. The picrate had m.p. 156-158°. Literature data [2]: for pyrazole, m.p. 70°, for its picrate, 159°.

b) By the reaction of 1,1,3-tribromo-3-acetoxypropane (Ib) with hydrazine hydrate. A solution of 0.85 g (0.017 mole) hydrazine hydrate * in 7 ml ethyl alcohol was added to a solution of 5.08 (0.015 mole) of (Ib) in 50 ml ethyl alcohol, after which a solution of 6 g (0.044 mole) of sodium acetate in 25 ml 50% ethyl alcohol was added dropwise, at the temperature of a 60-70° bath, at a rate proportional to the rate of appearance of an acid reaction to congo red. At first the acid reaction appeared fairly rapidly, but the last third of the solution was added much more slowly. The total duration of the reaction was 1.5-2 hours. The pale yellow solution obtained was boiled for 1 hour on the water bath, the alcohol removed in vacuo, the aqueous residue cooled, made alkaline with 20% caustic soda solution and extracted repeatedly with ether. The extract was dried with potassium carbonate and the ether evaporated. Almost all the residue crystallized; weight of crystals 0.81 g. After vacuum distillation at 60° 0.54 g (55%) of pyrazole (IV) was obtained in the form of colorless crystals. M.p. 69-70°, m.p. of picrate 157-158°. Neither the pyrazole nor its picrate gave a melting point depression when mixed with the materials obtained by the other method (method "a").

c) By the reaction of 1,1-dichloro-3-bromo-3-acetoxypropane (Ia) with hydrazine hydrate. 3.8 g (0.015 mole) of (Ia)** was dissolved in 35 ml 50% ethyl alcohol and 0.9 g (0.018 mole) of hydrazine hydrate added to the solution. The mixture was heated for 2.5 hours on the water bath at 65°. The solution was filtered with charcoal, evaporated in vacuo to 1/3 of the original volume, made alkaline with 20% caustic soda solution and extracted repeatedly with ether. Evaporation of the ether and vacuum distillation yielded 0.66 g (65%) of pyrazole with m.p. 68-69°, which gave no melting point depression when mixed with samples prepared by methods "a" and "b".

1-Phenylpyrazole. a) From 1,1-dichloro-3-bromo-3-acetoxypropane (Ia). A solution of 2.3 g (0.016 mole) of phenylhydrazine hydrochloride in 15 ml hot water was added to a solution of 3.8 g (0.015 mole) of (Ia) in 20 ml alcohol. The mixture obtained was heated for 3 hours at the boil, after which the alcohol was removed in vacuo, the residue made alkaline with 20% caustic soda solution, extracted with ether, and the brown oil which remained after removal of the ether was vacuum distilled. This yielded 1.3 g (61%) of a pale yellow liquid, b.p. 107-108° at 6 mm.

Found %: N 19.18, 19.26. $C_9H_8N_2$. Calculated %: N 19.43.

b) From 1,1,3-tribromo-3-acetoxypropane (Ib). A solution of 2.47 g (0.017 mole) of phenylhydrazine hydrochloride in 15 ml hot water was added to a solution of 5.08 g (0.015 mole) of (Ib) in 30 ml ethyl alcohol, after which a solution of 8.16 g (0.06 mole) of sodium acetate in 9 ml water and 20 ml ethyl alcohol was added gradually to the reaction mixture at a rate proportional to the rate of appearance of an acid reaction to congo red. During the addition of the substances mentioned, the temperature of the water bath was raised to 70-80° and when all had been added the mixture was boiled for 2.5 hours under reflux. The alcohol was distilled off in vacuo and the residue made alkaline with 20% caustic soda solution and extracted with ether. The ether was removed and the 1-phenylpyrazole (V) obtained was vacuum distilled; b.p. 107-108° at 6 mm.

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* The yield of pyrazole is not reduced when hydrazine hydrochloride is used instead of hydrazine hydrate.

** The 1,1-Dichloro-3-bromo-3-acetoxypropane (Ia) was prepared as described by Kharasch [5] with this difference, that benzoyl peroxide was used instead of acetyl peroxide to initiate the radical reaction. In this case the yield is lowered from 40% to 20%, calculated from the vinyl acetate. When an attempt was made to use the azodinitrile of isobutyric acid as an initiator for the reaction, the starting products were recovered unchanged.

1.35 g (63%) of pale yellow liquid was obtained. The aurate had m.p. 178-180° (with decomp.). Literature data for the aurate of 1-phenylpyrazole [9]: m.p. 180.5-181.5°.

Isoxazole. a) From 1,1-dichloro-3-bromo-3-acetoxypropane (Ia). 1.42 g (0.02 mole) of hydroxylamine hydrochloride was added to a solution of 5 g (0.02 mole) of (Ia) in 15 ml 60% ethyl alcohol. The mixture was heated at the boil for 1.5 hours, after which the mixture of alcohol, water and isoxazole was distilled into a receiver containing a saturated solution of cadmium chloride. A precipitate of the slightly impure double salt of isoxazole and cadmium chloride was obtained; weight 3.85 g (76%).

Found %: N 4.11, 4.39. $C_3H_3ON \cdot CdCl_2$. Calculated %: N 5.54.

The double salt was purified by boiling with water and the double salt again recovered from the distillate, weight 2.1 g (42%).

Found %: N 5.41, 5.26. $C_3H_3ON \cdot CdCl_2$. Calculated %: N 5.54.

b) From 1,1,3-tribromo-3-acetoxypropane (Ib). A solution of 2.8 g (0.04 mole) of hydroxylamine hydrochloride in 8 ml water was added to a solution of 10 g (0.029 mole) of (Ib) in 60 ml ethyl alcohol, after which a solution of 12.2 g (0.09 mole) of sodium acetate in 10 ml of water was added gradually with the mixture boiling, at such a rate that the solution remained weakly acid to congo red. When all had been added the mixture was boiled for half an hour and the mixture of alcohol, water and isoxazole distilled off. A saturated solution of cadmium chloride was added to the distillate until precipitation was complete. The precipitate of 4.05 g (55%) of the double salt of isoxazole and cadmium chloride obtained was decomposed by boiling with a small amount of water after which the double salt was again precipitated from the distillate with a saturated cadmium chloride solution. 2.3 g (31%) of the double salt was obtained.

Found %: N 5.34, 5.44. $C_3H_3ON \cdot CdCl_2$. Calculated %: N 5.54.

The dianil of malondialdehyde (VII). 1.2 g (0.013 mole) aniline was added to a solution of 2 g (0.006 mole) of (Ib) in 15 ml alcohol and the mixture boiled under reflux for 1.5 hours. The addition of 8 ml water to the cooled solution produced an orange crystalline precipitate of the dianil hydrobromide, weight 1.4 g (80%), m.p. 208°. M.p. 211-212° after recrystallization from methanol (1:1).

Found %: Br 26.48, 26.54; N 9.10, 9.10. $C_{15}H_{14}N_2$. HBr. Calculated %: Br 26.37; N 9.23.

0.5 g of the hydrobromide was dissolved in 15 ml ethyl alcohol and a solution of 0.65 g of caustic soda in 2 ml water was added to convert it to the base. After 1 hour the solution obtained was diluted with water and the precipitate of the dianil base filtered off. Weight 0.2 g, m.p. 114-115° from dilute alcohol. Literature data [10]: m.p. of dianil base 115°.

Similar treatment of 1 g (0.004 mole) of (Ia) yielded 0.56 g (64%) of the dianil base with m.p. 112-114°.

2-Aminopyrimidine (VIII). A solution of 1.0 g (0.0105 mole) of guanidine hydrochloride in 25 ml anhydrous ethyl alcohol was saturated at 0° with dry hydrogen chloride; 3.4 g (0.01 mole) of (Ib) in 5 ml anhydrous alcohol was added to the mixture and saturation of the mixture with hydrogen chloride was continued at room temperature for 3 hours, after which the passage of hydrogen chloride was stopped and the mixture boiled for 2.5 hours. The alcohol was removed in vacuo and 3 ml water and excess 30% caustic soda solution added to the residue. The mass obtained was dried in a vacuum desiccator and extracted with boiling benzene. This yielded 0.75 g (79%) of material with m.p. 125-126°. The substance gave no melting point depression when mixed with a sample of 2-aminopyrimidine prepared by another method.

When the reaction was carried out in similar conditions with 2.5 g (0.01 mole) of (Ia), 0.68 g (71%) of 2-aminopyrimidine with m.p. 125-126° was obtained.

SUMMARY

1. 1,1,3-Tribromo-3-acetoxypropane (Ib) has been prepared by the action of bromoform on vinyl acetate in the presence of benzoyl peroxide.

2. The reaction of 1,1-dihalogeno-3-bromo-acetoxypropanes with semicarbazide, hydrazine, phenylhydrazine, hydroxylamine, aniline and guanidine has yielded respectively the amide of pyrazole-1-carboxylic

acid, pyrazole, 1-phenylpyrazole, isoxazole, the dianil of malondialdehyde and 2-aminopyrimidine.

3. The 1,1-dihalogeno-3-bromo-3-acetoxypropanes, as a result of their reactions with the nitrogen-containing compounds listed above, may be regarded as functional derivatives of malondialdehyde.

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STUDIES IN THE FIELD OF THIOSULFONIC ACIDS

I. THE SYNTHESIS AND ANTIBACTERIAL PROPERTIES OF CERTAIN ALKYL ESTERS OF PROPANE-1-THIOSULFONIC ACID AND BUTANE-1-THIOSULFONIC ACID

B. G. Boldyrev, A. K. Litkovets and T. A. Trofimova

The esters (I) of thiosulfonic acids for a long time attracted the attention of many research workers, but for two decades after 1925 no new works in this field appeared. Only in 1950 did M. A. Belous and I. Ya. Postovsky [1] report the synthesis of the allyl ester (II) of allylthiosulfonic acid, which in structure and properties resembles the active principle of garlic [2,3]—the natural antiobiotic allicin (III), on the strength of which compound (II) was named by the authors "pseudo-allicin". This synthesis was undertaken in the hope of obtaining a new antibacterial substance; as microbiological tests showed, pseudo-allicin (II) does indeed kill gram-positive and gram-negative bacteria, but its activity is less than that of allicin by a factor of approximately two. At the same time it has a low stability and considerable toxicity, which prevents its use as an antibacterial agent. The analogs (IV) of allicin which were prepared by Covallito et al. [4] proved more interesting than allicin itself, since in a number of cases they excel the latter in antibacterial activity. These compounds, too, however, have a low stability, expecially at high temperatures.

$$\underset{\text{(I)}}{R-SO_2-S-R'}$$

$$\underset{\text{(II)}}{CH_2{=}CH-CH_2-SO_2-S-CH_2-CH{=}CH_2} \quad \underset{\text{(III)}}{CH_2{=}CH-CH_2-SO-S-CH_2-CH{=}CH_2}$$

$$\underset{\text{(IV)}}{\text{Alkyl}-SO-S-\text{Alkyl}} \quad \underset{\text{(V)}}{\text{Alkyl}-SO_2-S-\text{Alkyl}}$$

$$\underset{\text{(VI)}}{CH_3-CH_2-SO_2-S-CH_2-CH_3} \quad \underset{\text{(VII)}}{CH_3-CH_2-SO-S-CH_2-CH_3}$$

$$\underset{\text{(VIII)}}{CH_3-SO_2-S-\text{Alkyl}} \quad \underset{\text{(IX)}}{CH_3-CH_2-SO_2-S-\text{Alkyl}}$$

When the analogs (V) of pseudo-allicin, i.e. the alkyl esters of alkanethiosulfonic acids, are considered, it is found that these compounds were unknown until recently, with the exception of the ethyl ester (VI) of ethanethiosulfonic acid [5,6]. A comparison of the antibacterial activity of this product with that of the analogous ester (VII) of ethanethiosulfinic acid has shown [6] that the former not only has as much activity as the ester (VII) but even exceeds it in its activity towards a number of bacteria.

This has given us reason to expect that among the esters of thiosulfonic acids may be found materials with a high antibacterial activity and practical interest, and has led us to undertake the present research. In addition, taking into consideration the fact that allicin belongs [7] to the group of phytocides—the characteristic defense materials of plants against microorganisms—we supposed that the ethers of thiosulfonic acids (and likewise of thiosulfinic acids) should possess high antibacterial activity especially against phytopathogenic

bacteria and fungi. To confirm these hypotheses we have synthesised [8,9] in the first place certain alkyl esters (VIII), (IX) of methane- and ethanethiosulfonic acids.

A study of the antibacterial activity of these compounds confirmed our ideas and showed* that the esters (VIII), (IX) exhibit a marked bacteriostatic (fungistatic and protistocidic) action on gram-positive, gram-negative and acid-resistant bacteria, various fungi, protozoa etc. We therefore decided to continue the study of the esters of thiosulfonic acids and in the present work we undertook the preparation of compounds (X) and (XI)—the alkyl esters of propane-1- and butane-1-thiosulfonic acids.

$$\underset{(X)}{CH_3{-}CH_2{-}CH_2{-}SO_2{-}S{-}Alkyl} \qquad \underset{(XI)}{CH_3{-}CH_2{-}CH_2{-}CH_2{-}SO_2{-}S{-}Alkyl}$$

The synthesis of the esters (X) and (XI) was carried out by us according to the well-known method [1] the essentials of which are expressed by the following sequence of reactions:

$$Alkyl \xrightarrow{Na_2SO_3} Alkyl{-}SO_3Na \xrightarrow{PCl_5} Alkyl{-}SO_2Cl \xrightarrow{KSH}$$
$$\longrightarrow Alkyl{-}SO_2{-}SK \xrightarrow{Alkyl\ Br} Alkyl{-}SO_2{-}S{-}Alkyl$$

By the reaction of propane- and butanesulfonyl chlorides with an aqueous solution of potassium hydrogen sulfide, subsequent evaporation of the reaction mass to dryness and treatment of the mixture of salts with butyl alcohol,we prepared, and separated in the pure state, potassium propane- and butanethiosulfonates, which have not been described before, in the form of colorless crystalline products. These salts were used by us for the further synthesis of the esters (X) and (XI); the latter were obtained by heating aqueous acetone solutions of the potassium thiosulfonates with alkyl bromides on the water bath for 10-20 hours in the case of esters with normal structures and for 120-160 hours in the case of the isopropyl and isobutyl esters respectively; when the time of heating was curtailed the yields of products were reduced sharply.

In addition, we checked the possibility of simplifying the method of synthesis of the esters (X) and (XI) by preparing them directly from the reaction mass after the preparation of the thiosulfonates without separating the latter; the tests carried out by us showed that in these conditions also the esters could be obtained in a fairly pure state, but the yields were approximately 1.5 times lower than when the same reactions were carried out with crystalline thiosulfonates. We also made an attempt to increase the yields of esters by using an excess of alkyl bromides in the synthesis, but we obtained results which were the reverse of those expected: the yields of esters in these tests not only were not increased but were even somewhat lowered as a result of the formation of side products with lower boiling points than the ethers themselves.

The alkyl esters of propane- and butanethiosulfonic acids prepared by us and given in the Table are not described in the literature; when they had been separated from the reaction mass and vacuum distilled they were obtained, like the esters (VIII) and (IX), as colorless oily mobile liquids with a sharp odor of garlic or onion which was sometimes very unpleasant. All these compounds are denser than water, but their specific gravity gradually decreases with increasing length of the hydrocarbon chain and with increase in molecular weight. The esters (X) and (XI) are quite stable at room temperature for an unlimited period of time (we observed their behavior for 4 years), only occasionally acquiring a pale yellow coloration which may be easily removed by

* All the main microbiological tests were carried out in the Institute of Microbiology of the Ukrainian SSR Academy of Sciences. We take this opportunity of expressing our gratitude to V. G. Drobotko, B. E. Eisenman, K. I. Beltyukovaya and S. I. Zelepukha for testing our specimens.

repeated distillation. These substances are also stable on heating to 120-140° and may be vacuum distilled (1-2 mm) without decomposition; they are sparingly soluble in water, miscible in all proportions with alcohols, ether, acetone, chloroform, benzene and other organic solvents.

The study of the antibacterial activity of these compounds carried out by the Institute of Microbiology of the Ukrainian SSR Academy of Sciences has shown that in tests in vitro the esters (X) and (XI) show a marked antibacterial action on the same types and strains of bacteria as the esters (VIII) and (IX) of methane- and ethanethiosulfonic acids; the antibacterial properties of the esters is altered only within narrow limits depending on their structures and only the isopropyl and isobutyl esters show a higher activity.

EXPERIMENTAL*

The sulfonates and chlorides of the acids required for the synthesis of the alkyl esters of propane- and butanethiosulfonic acids were synthesized by us according to the well-known methods [1, 11]; the boiling point of the chlorides after vacuum distillation agreed with the literature data [12,13]. The potassium salts of the thiosulfonic acids and the alkyl esters of the latter were also synthesized according to a method described earlier [1, 10].

The potassium salts of propane-1- and butane-1-thiosulfonic acids. An equimolecular amount of propane-(or butane-)sulfonyl chloride was added with cooling and stirring to an aqueous solution of potassium hydrogen sulfide; the medium remained alkaline to phenolphthalein until reaction was complete. To dissolve the sulfur which separated during this process, the reaction mass was heated on a water bath for half an hour, treated with active charcoal, filtered and evaporated to dryness. The dry mixture of salts was broken up and treated with butyl alcohol to extract the thiosulfonates. After recrystallization from anhydrous alcohol the latter were obtained as colorless materials with m.p. 135-136° and 145° respectively. These salts dissolved very readily in water, less readily in boiling ethyl and butyl alcohols, and were insoluble in ether, benzene, chloroform and acetone. The yields of the pure products were 62.3 and 70.0%.

The potassium propylthiosulfonate crystallized from anhydrous ethyl alcohol in the form of compact square plate-like crystals and from butyl alcohol in the form of very fine square plates which rapidly lost their original form and acquired a flaky structure.

Found %: S 35.69. $C_3H_7O_2S_2K$. Calculated %: S 35.96.

The potassium butylthiosulfonate crystallized from anhydrous ethyl alcohol in the form of long smooth crystals of irregular shape and from butyl alcohol in the form of rectangular plates. The butylthiosulfonate crystals on the objective glass lost their shape in a few seconds as a result of the extremely hygroscopic nature of this salt, and deliquesced rapidly in air.

Found %: S 33.35, 33.47. $C_4H_9O_2S_2K$. Calculated %: S 33.34.

The alkyl esters of propane-1- and butane-1-thiosulfonic acids were obtained by heating aqueous acetone solution of the corresponding thiosulfonates on the water bath with equimolecular amounts of the alkyl halides for 4-20 hours in the case of the esters with normal structure and for 120-160 hours in the case of the isopropyl and isobutyl esters, respectively; allyl bromide reacted with the thiosulfonates at room temperature in the course of 1 hour. The potassium bromide which was precipitated during the reaction was filtered off, the acetone distilled and the residue extracted with ether; the extracts were then washed with water and dried, the ether distilled off and the residue vacuum distilled at 1-2 mm. The use of excess alkyl bromides somewhat lowered the yields of the final esters. Test experiments on the synthesis of the alkyl esters using the reaction masses obtained by the reaction of the sulfonyl chlorides with an aqueous solution of potassium hydrogen sulfide and containing the thiosulfonates instead of the crystalline thiosulfonates themselves, showed that the alkyl esters are obtained in this way in considerably lower yields (approximately 1.5 times lower) as a result of the formation of low-boiling side reaction products.

* In conjunction with M. A. Ivakina and L. G. Voskres

Alkyl Esters of Propane-1- and Butane-1-Thiosulfonic Acids
Alkyl$-SO_2-S-$Alkyl'

Specimen No.	Alkyl	Alkyl'	Boiling point (1-2 mm)	d_{20}^{20}	n_D^{20}	MR_D Found	MR_D Calc.	Sulfur content (%) Found	Sulfur content (%) Calc.	Yield (in %)
1	$CH_3-CH_2-CH_2-$	CH_3-CH_2	100–102	1.1557	1.4955	42.50	42.52	37.96	38.11	57.0
2		$CH_3-CH_2-CH_2-$	112–114	1.1287	1.4935	46.97	47.14	35.08	35.19	60.7
3		$(CH_3)_2CH-$	97–98	1.1189	1.4904	47.14	47.14	35.16	35.19	56.0
4		$CH_2{=}CH-CH_2-$	106–108	1.1359	1.5021	46.85	46.67	35.43 35.35	35.57	71.4
5		$CH_3-CH_2-CH_2-CH_2-$	117	1.0880	1.4884	52.02	51.76	32.58	32.68	56.0
6		$(CH_3)_2CH-CH_2-$	114–115	1.0949	1.4896	51.80	51.76	32.48	32.68	41.7
7	$CH_3-CH_2-CH_2-CH_2-$	CH_3-CH_2-	122–123	1.1088	1.4877	47.35	47.14	35.28	35.18	70.0
8		$CH_3-CH_2-CH_2-$	128–129	1.0914	1.4888	51.90	51.76	32.79	32.67	48.0
9		$(CH_3)_2CH-$	121–122	1.0931	1.4900	51.93	51.76	32.62	32.67	38.2
10		$CH_2{=}CH-CH_2-$	127	1.0923	1.4889	51.33	51.29	33.11	33.00	83.0
11		$CH_3-CH_2-CH_2-CH_2-$	134–135	1.0613	1.4822	56.53	56.37	30.31	30.49	65.0
12		$(CH_3)_2CH-CH_2-$	128	1.0709	1.4887	56.66	56.37	30.62	30.49	40.0

• The refractions of the SO_2 group and the sulfide sulfur S were taken by us, as in previous works [8,9] as equal to 8.63 and 8.00 respectively (average values); the exaltation of the group $-SO_2-S-$ was taken as equal to +0.6. The physico-chemical constants of some of the esters prepared by us earlier [10] have been made more precise in the present work.

SUMMARY

1. The previously unknown potassium salts of propane-1- and butane-1-thiosulfonic acids have been prepared by the reaction of propane- and butanesulfonyl chlorides with an aqueous solution of potassium hydrogen sulfide and isolated in crystalline form.

2. 12 alkyl esters of propane-1-thiosulfonic and butane-1-thiosulfonic acids, which are not described in the literature, have been prepared by the condensation of the potassium thiosulfonates with alkyl bromides and their characteristics obtained.

3. The antibacterial properties of the esters (X) and (XI) have been studied; it has been established that these compounds exhibit a wide spectrum of antibacterial action and in tests in vitro show bacteriostatic, fungistatic and protistocidic action on gram-positive, gram-negative and acid-resistant bacteria, various fungi and protozoa; the activity of the esters studied varies within narrow limits depending on their structure.

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** In Russian.

BISULFITE COMPOUNDS OF 4-NITROSO-1-NAPHTHOL AND 1-NAPHTHOL

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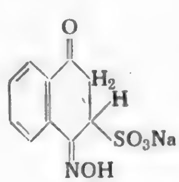
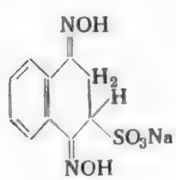
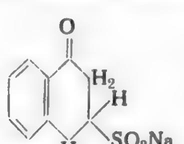
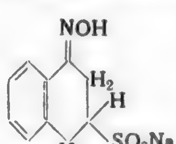
The ability of 4-nitroso-1-naphthol to form a compound with sodium bisulfite has been known for a long time [1], but there are no experimental data on the composition and structure of this compound. The bisulfite compound of 4-nitroso-1-naphthol prepared by us has the composition $C_{10}H_6(OH)(NO) \cdot NaHSO_3 \cdot H_2O$. It is easily decomposed by caustic soda to the sodium salt of 4-nitroso-1-naphthol and sulfite, and is converted by the action of hydroxylamine hydrochloride in the presence of sodium acetate to a material with the composition $C_{10}H_8O_2N_2 \cdot NaHSO_3 \cdot 2.5\ H_2O$. The latter is more stable to alkalis than the bisulfite compound of the nitrosonaphthol but on heating with 8% caustic soda it decomposes into the sodium salt of 1,4-naphthoquinone dioxime and sulfite, and is converted by the action of hydrochloric acid into the bisulfite compound of 4-nitroso-1-naphthol. These properties show that the substance is the bisulfite compound of 1,4-naphthoquinone dioxime. The conversion of the bisulfite compound of nitrosonaphthol into the bisulfite compound of naphthoquinone dioxime confirms the structure proposed earlier [2] for the bisulfite compound of nitrosonaphthol as the product of bisulfite addition to the carbon double bond 2,3 (I), while the structure of the bisulfite compound of naphthoquinone dioxime can be represented by the formula (II):


(I)


(II)

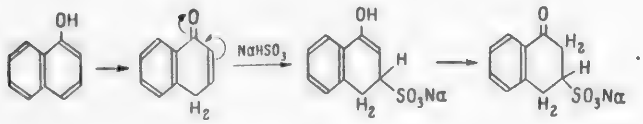
It has recently been reported [3] that in the decarboxylation of 1-hydroxy-2-naphthoic acid with sodium bisulfite, 1-naphthol is formed first of all, followed by its bisulfite compound. Taking this sequence of reactions into account, we prepared the bisulfite compound of 1-naphthol for further study of its properties by boiling a mixture of 1-naphthol with sodium bisulfite. With a bisulfite to naphthol ratio of 10:1 and 27-30 hours reaction time the yield of the bisulfite compound was 82.6-86.8% while the residue of naphthol was 11.8-9.4% of the amount taken. Tests showed that the bisulfite compound of 1-naphthol is converted by the action of hydroxylamine hydrochloride in the presence of sodium acetate into the oxime of the bisulfite compound, even at room temperatures, while the use of semicarbazide hydrochloride instead of hydroxylamine hydrochloride leads to the formation of the corresponding semicarbazone. These reactions show that the bisulphite compound of naphthol is tetralonesulfonic acid (III). The structure of the oxime of the bisulfite compound may be represented by the formula (IV) and the structure of the semicarbazone by formula (V).


(III)


(IV)


(V)

The conversion of 1-naphthol into the bisulfite compound (III) takes place according to the scheme:



Further experimental data on the position of the sulfonic acid group in the bisulfite compound will be communicated later.

The oxime of the bisulfite compound was isolated as the sodium and barium salts, the semicarbazone as the sodium salt. Both the oxime and the semicarbazone are much more stable to alkalis than the bisulfite compound of naphthol, but are converted to the latter in acid medium. A formula for the bisulfite compound of naphthol similar to (III) was put forward earlier [2], but without experimental foundation. Indirect confirmation for the formula may be provided by analogy from the nitration of 1-tetralone [4], 1-tetralone-3-carboxylic acid [5] and the bisulfite compound of 1-naphthol [3] which leads to mixtures of the corresponding 7- and 5-nitroderivatives.

EXPERIMENTAL

The bisulfite compound of 4-nitroso-1-naphthol (I). 4-Nitroso-1-naphthol was prepared by nitrosation of 1-naphthol and separated from the 2-nitroso-1-naphthol formed at the same time with sodium bisulfite [1]. 21 g 4-nitroso-1-naphthol was stirred with 50 g 37% sodium bisulfite and 45 ml water at 20° for 8 hours and the whole left for 16 hours. The slight brown precipitate was filtered off, and the bisulfite compound separated from the solution with sodium chloride (20% by volume); yield 35 g. Fine colorless plates (from aqueous alcohol), very readily soluble in cold water, sparingly soluble in alcohol. Completely decomposed to sulfite and the sodium salt of nitrosonaphthol by 9% caustic soda for 15 minutes at 16°; loses water of crystallization at 100°; decomposes at 110°.

Found %: H_2O 6.01; Na 7.64; C 43.17; H 3.31. $C_{10}H_8O_5NSNa \cdot H_2O$. Calculated %: H_2O 6.10; Na 7.79. $C_{10}H_8O_5NSNa$. Calculated %: C 43.31; H 2.91.

The bisulfite compound of 1,4-naphthoquinone dioxime (II). A solution of 11.08 g of the bisulfite compound of 4-nitroso-1-naphthol, 3.08 g hydroxylamine hydrochloride and 6.53 g crystalline sodium acetate in 200 ml water was boiled for 1 hour. When the solution was cooled 0.65 g 4-nitroso-1-naphthol was precipitated; yellowish needles (from dilute alcohol) with b.p. 193° (decomp.), soluble in dilute sodium carbonate solution. When the filtrate was evaporated the bisulfite compound of 1,4-naphthoquinone dioxime was precipitated; yield 9.31 g. Colorless plates (from water), readily soluble in water and soluble with difficulty in alcohol. Unaffected by 9% caustic soda in the conditions given above and slightly decomposed by 37% caustic soda at 18° for 24 hours. An acidified solution of the substance acquired a yellow color on boiling for a short period, and when this was made alkaline and again acidified sulfur dioxide was evolved and a precipitate (needles) of 4-nitroso-1-naphthol with m.p. 187° (decomp.) was obtained. The precipitate was soluble in dilute sodium carbonate solution and formed the bisulfite compound of nitrosonaphthol with sodium bisulfite.

Found %: H_2O 13.40; Na 7.69. $C_{10}H_9O_5N_2SNa \cdot 2.5\ H_2O$. Calculated %: H_2O 13.36. $C_{10}H_9O_5N_2SNa$. Calculated %: Nà 7.87.

1,4-Naphthoquinone dioxime. A solution of 2 g of the bisulfite compound of naphthoquinone dioxime and 5 ml 38.7% caustic soda in 25 ml water was heated to boiling point, cooled to 15° and poured into a mixture of 15 ml 34.4% hydrochloric acid and 50 ml water. Sulfur dioxide was evolved and a yellowish precipitate of naphthoquinone dioxime was obtained; yield 0.88 g. Yellowish needles and plates (from dilute alcohol),

gradually changing to prisms; m.p. 217° (decomp.). The diacetyl derivative was prepared by heating 0.6 g of the dioxime with 6 ml of acetic anhydride on the water bath (1 hour) and diluting the mass with water; yield 0.8 g. Prisms (from alcohol), m.p. 167.5-168°. For comparison, naphthoquinone dioxime and its diacetyl derivative were prepared from 4-nitroso-1-naphthol. A solution of 2 g nitrosonaphthol and 3.25 g hydroxylamine hydrochloride in a mixture of 200 ml water and 110 ml alcohol was boiled for 19 hours and cooled. The naphthoquinone dioxime which precipitated was filtered off and washed with 5% sodium carbonate solution and water; yield 1.6 g. Prisms (from dilute alcohol), m.p. 215° (decomp.). Diacetyl derivative: prisms (from alcohol), m.p. 168.5-169°. A mixture of the naphthoquinone dioximes: m.p. 216° (decomp.); a mixture of the diacetyl compounds: m.p. 168-168.5°.

The bisulfite compound of 1-naphthol (III). A mixture of 28.8 g 1-naphthol, 602 g 34.6% sodium bisulfite and 1-2 ml methyl alcohol was boiled under reflux with stirring and periodic passage of sulfur dioxide for 28 hours. The solution obtained was acidified with 200 ml 34.4% hydrochloric acid and the sulfur dioxide removed by passing air through at 20-50°. The naphthol which separated was extracted with ether and removed from the ether extract with alkali; acidification of the alkaline solution yielded 2.7-3.4 g (9.4-11.8%) of naphthol, m.p. 91-92°. The aqueous solution of the bisulfite compound was partly neutralized with sodium carbonate and evaporated to 800 ml. Analysis showed that the solution contained 25-23.8 g (86.8-82.6%) naphthol in the form of the bisulfite compound. 60 g sodium chloride was added to 775 ml of the solution, the mixture kept at 10° for 5 hours, the bisulfite compound filtered off and washed with alcohol; yield 86.1-90.6% of product calculated from 35.7-31.5 g in 800 ml. The bisulfite compound was recrystallized from 80% alcohol.

The oxime of the bisulfite compound of naphthol (IV). 3.4 g hydroxylamine hydrochloride was added to a solution of 11.03 g 90.05% of the bisulfite compound of naphthol in 40 ml water at 20°, followed by 32 g crystalline sodium acetate over a period of 45 minutes and the mixture left at 20-21° for 22 hours (the reaction product began to precipitate after 45 minutes). The mass was cooled to 0°, the precipitate filtered off and washed with alcohol; yield 9.97 g (94.7%). The substance was purified by dissolving in water at ordinary temperatures and precipitation with alcohol.

The sodium salt: long colorless plates, soluble very readily in water and with difficulty in alcohol. No sulfurous acid was split off on treatment with 37% caustic soda at 18° for 24 hours. When an acidified solution was boiled, made alkaline and again acidified, sulfur dioxide and naphthol were produced. The substance contained no water of crystallization and decomposed at 140-150°.

Found %: C 45.37; H 4.10; N 5.39; Na 8.48. $C_{10}H_{10}O_4NSNa$. Calculated %: C 45.61; H 3.83; N 5.32; Na 8.74.

The barium salt (prepared from the sodium salt): long, colorless hexagonal plates, soluble in water but much less so than the sodium salt; loses water of crystallization at 110°.

Found %: H_2O 10.45; Ba 22.22. $C_{20}H_{20}O_8N_2S_2Ba \cdot 4H_2O$. Calculated %: H_2O 10.44. $C_{20}H_{20}O_8N_2S_2Ba$. Calculated %: Ba 22.23.

The semicarbazone of the bisulfite compound of naphthol (V). A solution of 5 g semicarbazide hydrochloride and 13 g crystalline sodium acetate in 20 ml water was added at 25° to a solution of 11.03 g 90.05% bisulfite compound of naphthol in 40 ml water and the mixture left at 25° for 18 hours (the reaction product began to precipitate after 1 hour). The mass was cooled to 0°, the precipitate filtered off and washed with alcohol; yield 13.95 g (97.1%). The substance was dissolved in water at ordinary temperatures and precipitated with alcohol. Long colorless prisms with pointed ends, readily soluble in water and soluble with difficulty in alcohol. The substance behaves towards alkalis and acids in a similar manner to the oxime of the bisulfite compound of naphthol. It loses water of crystallization at 100-110°; the dried material is hygroscopic.

Found %: H_2O 14.85; N 11.81; Na 7.44. $C_{11}H_{12}O_4N_3SNa \cdot 3H_2O$. Calculated %: H_2O 15.04; N 11.69. $C_{11}H_{12}O_4N_3SNa$. Calculated %: Na 7.53.

SUMMARY

1. The bisulfite compound of 4-nitroso-1-naphthol is converted by the action of hydroxylamine to the

bisulfite compound of 1,4-naphthoquinone dioxime, which breaks down in alkaline medium into sulfite and 1,4-naphthoquinone dioxime, and in acid medium is hydrolyzed to the bisulfite compound of nitrosonaphthol.

2. The bisulfite compound of 1-naphthol is converted by hydroxylamine into the oxime of the bisulfite compound and by semicarbazide into the semicarbazone of the bisulfite compound of naphthol.

3. The structure of the bisulfite compound of 1-naphthol may be represented by the formula of 1-tetralonesulfonic acid.

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A STUDY OF THE COMPARATIVE REACTIVITY OF THE HYDROXYL GROUPS IN CELLULOSE*

II. THE DISTRIBUTION OF METHOXY GROUPS IN PARTLY METHYLATED CELLULOSE PREPARED IN A MEDIUM OF BASES

V. Derevitskaya, Yu. Kozlova and Z. Rogovin

In a study of the distribution of methoxy groups in methylcellulose prepared in alkaline solution, we have shown that in the formation of alkali cellulose and subsequent methylation the greater reactivity is exhibited by the secondary hydroxyl groups [1]. The present work is devoted to a study of the distribution of methoxy groups in methylcellulose with $\gamma = 100$, prepared in a medium of quaternary ammonium bases by methylation of the copper-sodium cellulose compound. The distribution of the methoxy groups in methylcelluloses prepared in a medium of quaternary ammonium bases has been studied by many workers, but extremely contradictory results have been obtained. Thus Mahoney and Purves [2] and Rebenfeld and Pacsu [3] show the regular distribution of methoxy groups in the elementary chain of methylcelluloses prepared in a medium of a quaternary ammonium base. Timell [4] shows the greater reactivity of primary hydroxyl groups in the same methylation conditions. As a result of studies on the distribution of methoxy groups in methylcelluloses prepared by methylation of the copper-sodium cellulose compound, the greater reactivity of the secondary hydroxyl groups has been established. Thus Piwonka [5] shows the greater reactivity of the hydroxyl group on the tertiary carbon atom in the methylation of the copper-sodium cellulose compound. Timell [4] has obtained data on the greater reactivity of the hydroxyl group of the second carbon atom in the same reaction.

We have used cellulose sulfite and "included" viscose rayon as the starting materials for methylation, and triethylbenzylammonium hydroxide as the quaternary ammonium base. The copper-sodium cellulose compound was obtained by treating the cellulose in turn with solutions of cupric chloride and alkali. The methylation was carried out with methyl iodide and dimethyl sulfate. A study was made of the distribution of methoxy groups between the primary and secondary carbon atoms in the methylcelluloses obtained. The number of free primary hydroxyl groups was determined by tritylation and in a number of methylcellulose specimens by iodination of the methylcellulose nitrates. The number of free glycol groups was determined by oxidation with periodic acid. The methylation in the presence of triethylbenzylammonium hydroxide was carried out in solutions containing 1-5% cellulose and 30-35% triethylbenzylammonium hydroxide.

The characteristics of the methylcelluloses obtained in triethylbenzylammonium hydroxide and the results of the examinations carried out are given in Table 1. As can be seen from the data in Table 1, the results of the determination of free hydroxyl groups by tritylation of the methylcellulose and by iodination of the methylcellulose nitrates are in fairly good agreement and show that in methylation in the medium of a quaternary ammonium base the greater reactivity is shown by the secondary hydroxyl groups, while in this case the reaction is more selective than in the case of the methylation of alkali cellulose. For methylcellulose prepared in alkaline medium Z amounts to $\sim$1.5, while for methylcellulose prepared in a medium of

* 57th communication in the series "A Study of the Structure and Properties of Cellulose".

TABLE 1

Starting Material	Methylating Agent	Concentration of cellulose in solution (%)	γ for methylcellulose (γOCH_3)	γ for the trityl ether of methylcellulose (γ tr.)	Number of OCH_3-groups on the C_6	Total γ for methylcellulose nitrate ($\gamma OCH_3 + \gamma + N_2$)	γ for the methylcellulose iodonitrate (γ I)	Number of OCH_3-groups on the C_6	Z*
Cellulose sulfite reprecipitated from solution in triethylbenzylammonium hydroxide.	–	–	–	100	–	–	–	–	–
Cellulose sulfite	CH_3I	5	86	86	14	287	76	24	1.8
	CH_3I	5	161	51	49	300	56	44	1.2
	$(CH_3)_2SO_4$	5	79	90	10	285	83	17	2.4
	$(CH_3)_2SO_4$	5	151	67	33	–	–	–	1.65
	CH_3I	1	94	81	19	–	–	–	1.97
	$(CH_3)_2SO_4$	1	90	86	14	–	–	–	2.7
Viscose rayon	CH_3I	1	80	80	20	–	–	–	1.5
	CH_3I	1	90	82	18	–	–	–	2.53
	$(CH_3)_2SO_4$	1	85	86	14	–	–	–	2.53

* Z—the ratio of the number of methoxy groups attached, on the average, to 1 secondary carbon atom to the number of methoxy groups on a primary carbon atom.

triethylbenzylammonium hydroxide Z on the average equals ~2.

In contrast to the methylcelluloses prepared in alkaline medium, where the distribution of methoxy groups does not depend on the methylating agent, the values of Z for methylcelluloses obtained in the medium of a quaternary ammonium base by methylating the cellulose with dimethylsulfate are somewhat higher than the values of Z for methylcelluloses prepared by methylation with methyl iodide. Thus the values of Z for methylcelluloses with $\gamma = 85$ and $\gamma = 90$, prepared by methylation with dimethyl sulfate, equal 2.53 and 2.7 respectively; the values of Z for methylcelluloses with $\gamma = 80$ and $\gamma = 90$, prepared by methylation with methyl iodide, equal 1.5 and 2 respectively.

The methylation of the copper-sodium cellulose compound was carried out heterogeneously. In order to reduce the influence of the cellulose structure, "included" viscose rayon was used as the starting cellulose material. The cellulose was treated with cupric chloride and then immersed in 35% caustic soda solution. The copper-sodium cellulose compound obtained was methylated. A study of the distribution of the methoxy groups in the methylcelluloses obtained (Table 2) has shown that in the methylcellulose specimens with values of γ up to 100 practically all the primary hydroxyl groups are free, and that consequently the methylation takes place exclusively at the secondary hydroxyl groups. The distribution of methoxy groups in the methylcelluloses obtained does not depend on the methylating agent.

TABLE 2

Specimen No.	Starting material	Methylating agent	γ for the methylcellulose (γ OCH_3)	γ for the trityl ether of the methylcellulose (γ tr.)	Number of OCH_3-groups on the C_6	Z
1	Viscose rayon	$(CH_3)_2SO_4$	94	97	3	15.2
2		CH_3I	86	103	0	
3		CH_3I	124	86	14	3.93

A comparison of data on the distribution of methoxy groups in methylcelluloses obtained in the presence of different bases shows that the nature of the base has a powerful influence on the distribution of the methoxy groups. This provides an indirect proof of the accuracy of the original thesis of our work that the methylation of cellulose in the presence of bases takes place at the hydroxyl groups which have reacted with the corresponding base, and that the structure of the methylcelluloses(with reference to the distribution of groups in the elementary chain) reflects the structure of the corresponding compound of the cellulose and the base.

The results of the determination of the number of free glycol groups in the specimens studied are given in Figures 1-3 in the form of the oxidation curves of the original cellulose and of the methylcelluloses with periodic acid. As in the previous work, the end of the oxidation of the free glycol groups was taken as indicated by the first plateau on the oxidation curve.

A comparison of the results of the examination of the methylcelluloses by oxidation and tritylation shows that in the methylcelluloses prepared by methylation of the copper-sodium cellulose compound (oxidation curves in Figure 3) the methoxy groups attached to the secondary carbon atoms are situated predominantly on one of the secondary carbon atoms. Thus in the methylcellulose with $\gamma = 86$, according to the tritylation data, all the methoxy groups are situated on the secondary carbon atoms (Specimen 3, Table 2). In this case the number of glycol groups on 100 glucose residues (γ gl.) should be 14; according to the oxidation data it equals 24 (Curve 2). In the methylcellulose with $\gamma = 94$, three methoxy groups are situated on a primary carbon atom (C_6), 91 methoxy groups on secondary carbon atoms ($C_{2,3}$) (Specimen 1, Table 2). The number of glycol groups according to the oxidation data equals 28 (Curve 3). With all the methoxy groups situated on one of the secondary carbon atoms it should equal 9, while with an equal distribution of the methoxy groups between the second and third carbon atoms it should equal 54.5.

For methylcelluloses obtained in a medium of triethylbenzylammonium hydroxide (Figures 1 and 2), the distribution of the methoxy groups between the secondary carbon atoms in the case of methylation by methyl

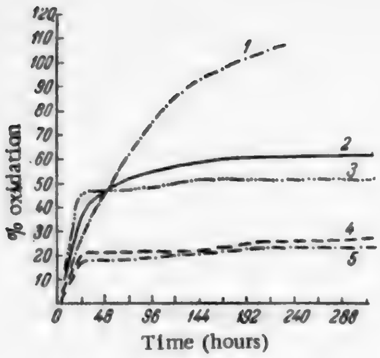

Fig. 1. The oxidation of cellulose sulfite (1) and methylcellulose with $\gamma = 79$ (2), $\gamma = 86$ (3), $\gamma = 151$ (4) and $\gamma = 161$ (5). Conditions: 0.05 M periodic acid solution, pH 4-4.1, temperature 20°.

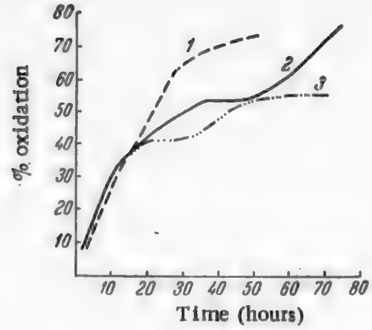

Fig. 2. The oxidation of cellulose sulfite (1) and methylcellulose with $\gamma = 90$ (2) and $\gamma = 94$ (3). Conditions: 0.5 M periodic acid solution, pH 4-4.1, temperature 20°.

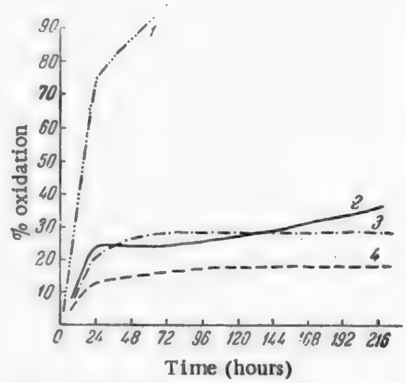

Fig. 3. The oxidation of viscose rayon (1) and methylcellulose with $\gamma = 86$ (2), $\gamma = 94$ (3) and $\gamma = 124$ (4). Conditions: 0.5 M periodic acid solution, pH 4-4.1, temperature 20°.

iodide is similar to that described for methylcelluloses prepared from the copper-sodium cellulose compound. For methylcellulose with $\gamma = 94$ there are 19 methoxy groups situated on the C_6 and 75 on $C_{2,3}$ (Table 1). If all the methoxy groups were situated on one of the secondary carbon atoms, the number of free glycol groups should be 25; according to the oxidation data, it equals 40 (Figure 2, Curve 3).

In methylcelluloses prepared by methylation of cellulose dissolved in triethylbenzylammonium hydroxide with dimethyl sulfate, the methoxy groups are almost equally distributed between the second and third carbon atoms. In methylcellulose with $\gamma = 79$, 10 methoxy groups are situated on the C_6 and 69 on the $C_{2,3}$ (Table 1). With an equal distribution of methoxy groups between C_2 and C_3 the number of glycol groups should be 65.5; according to the oxidation data it equals 59 (Figure 1, Curve 2). Approximately the same distribution of methoxy groups between C_2 and C_3 is observed in methylcelluloses with $\gamma = 90$ (Table 1, Figure 2, Curve 3).

The influence of the methylating agent on the distribution of the methoxy groups between the second and third carbon atoms, as between the primary and secondary carbon atoms, is observed only when the cellulose is methylated in triethylbenzylammonium hydroxide. This fact is difficult to explain at the present stage of study.

EXPERIMENTAL

The starting materials were viscose rayon and cellulose sulfite, treated in the way described in a previous communication [1], and "included" viscose rayon. For the "inclusion", the newly-formed viscose rayon was washed with water until neutral and wrung out, then treated several times with small portions of methanol to remove the main bulk of the water after which it was immersed overnight in a large volume of dry methanol (1 liter for 100 g thread) to remove the last traces of water. After 24 hours the methanol was poured off, the thread was wrung out and treated in similar fashion with benzene. The thread was then wrung out, dried in air and then in a vacuum desiccator at room temperature.

The methylation of cellulose dissolved in an aqueous solution of triethylbenzylammonium hydroxide. The cellulose sample (cellulose sulfite with D.P. = 390 or viscose rayon) was dissolved at room temperature in an aqueous solution of triethylbenzylammonium hydroxide of concentration 330-340 g/liter in a three-necked flask fitted with dropping funnel, stirrer and reflux condenser. With vigorous stirring a transparent solution was obtained approximately 1 hour after dissolution. 1 and 5% cellulose solutions were prepared. The methylating agent was added to the solution obtained over a period of 1 hour from a dropping funnel. In the methylation of cellulose in 5% solution to prepare methylcellulose with $\gamma = 100$, 2.5 mole of dimethyl sulfate or methyl iodide was added for 1 mole cellulose; for the methylation of cellulose in 1% solution—12 mole for 1 mole cellulose. Methylation was carried out for 4 hours at 35-40°. The methylcellulose obtained was precipitated in the form of flakes by pouring the solution into a large volume of methanol or acetone. The precipitate was settled, filtered off and washed first with methanol acidified with hydrochloric acid and then with methanol and acetone. The product was washed until neutral, dried in air and then in a vacuum drying oven at 60° and analysed.

The methylation of the copper-sodium cellulose compound. The sample of "included" viscose rayon was immersed in a solution of 2.85 g $CuCl_2 \cdot 2H_2O$ in 25 ml water and stirred for 10-15 minutes. The cellulose was then wrung out and added to toluene in a three-necked flask fitted with stirrer, dropping funnel and reflux condenser. The mixture was stirred for 10 minutes, 12 ml 35% caustic soda solution added and stirring continued for 4 hours at 0°. Dimethyl sulfate (3.9 mole to 1 mole of cellulose) was then added to the resultant suspension of the copper-sodium cellulose compound in toluene and methylation continued for 30-36 hours at 35-40° and 20-36 hours at room temperature. When methylation was finished, a large volume of methanol acidified with hydrochloric acid was added to the pasty dark brown mass. The flakes of methylcellulose which separated were filtered off, washed with acidified methanol and then with methanol alone until all the cupric chloride and hydrochloric acid were removed, and then with acetone. The methylcellulose obtained was dried in air then in a vacuum drying oven at 60° and analysed. In the case of the methylation with methyl iodide the copper-sodium cellulose compound was wrung out to 3 times its weight and methylated in a sealed glass ampoule (26 mole methyl iodide to 1 mole cellulose) for 20-36 hours at 40° and 23-26 hours at room temperature. The methylcellulose obtained was treated as described above. For the determination of the methoxy group content and the study of the distribution of the methoxy groups in the methylcelluloses obtained, the same methods were used as described in a previous communication [1].

SUMMARY

1. A study has been made of the distribution of methoxy groups in partly methylated cellulose obtained by the action of methyl iodide and dimethyl sulfate on cellulose in the presence of triethylbenzylammonium hydroxide and by methylation of the copper-sodium compound of cellulose.

2. In the reaction of cellulose with triethylbenzylammonium hydroxide and subsequent methylation, the greatest reactivity is exhibited by the secondary hydroxyl groups. The number of methoxy groups situated on the average on 1 secondary carbon atom in methylcellulose with $\gamma \approx 100$ is approximately 2 times greater than

the number of methoxy groups on the primary carbon atom.

3. The most selective reaction takes place in the methylation of the copper-sodium compound of cellulose. In the formation of methylcellulose with $\gamma \approx 100$ the reaction practically takes place only at the secondary hydroxyl groups. The results of the determination of the number of free glycol groups by oxidation with periodic acid show that the methoxy groups are situated for the most part on one of the secondary carbon atoms.

4. The distribution of methoxy groups in methylcellulose prepared in the presence of triethylbenzylammonium hydroxide depends on the nature of the methylating agent.

5. The distribution of methoxy groups in methylcelluloses with $\gamma \approx 100$, obtained by the action of the same methylating agent but in a medium of different bases, is variable, which indicates that the methylation of the cellulose takes place at hydroxyl groups which have reacted with the corresponding base.

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A STUDY OF THE COMPARATIVE REACTIVITY OF THE HYDROXYL GROUPS IN CELLULOSE*

III. THE DISTRIBUTION OF METHOXY GROUPS IN PARTLY METHYLATED CELLULOSE OBTAINED BY THE METHYLATION OF CELLULOSE WITH DIAZOMETHANE

V. Derevitskaya, Yu. Kozlova and Z. Rogovin

In previous communications [1,2] the results are given of a study of the distribution of methoxy groups in methylcelluloses prepared in the presence of different bases (alkali, a quaternary ammonium salt and the copper-sodium compound). In this case the structure of the methylcellulose (with reference to the distribution of the groups between the carbon atoms in the elementary link) is to a considerable extent determined by the structure of the compound formed by the cellulose and the corresponding base: the alkali cellulose, the compound of the cellulose with the quaternary ammonium base or the copper-sodium cellulose compound. The reaction of cellulose with diazomethane provides a natural example of the methylation of cellulose without preliminary preparation of a compound of cellulose and a base. In this case the distribution of the methoxy groups in the methylcellulose obtained is determined only by the nature of the methylating agent. Diazomethane readily methylates carboxyl oxygen, phenols and enols. It was therefore expected that in the action of diazomethane with cellulose the first groups to be methylated would be the secondary hydroxyl groups. The distribution of methoxy groups in the elementary link of partly methylated cellulose prepared by methylation with diazomethane has been studied by Sitch [3]. Methylcellulose with γ = 68 was hydrolyzed completely and the hydrolysis products were analyzed by paper chromatography. Glucose, mono-, di- and tri-methylglucose were found in the hydrolysis products in the ratio 2:4:4:1. On the basis of the data obtained the author concluded that the three hydroxy groups of the cellulose were methylated to the same extent by the diazomethane. This conclusion cannot be taken as justified, since the author did not determine the position of the methoxy groups in the methylglucose fractions isolated.

The methylation of cellulose with diazomethane is carried out in a medium of ether, in which the cellulose does not swell. To reduce the influence of the cellulose structure on the rate and regularity of the methylation process with diazomethane, we took as our starting material "included" viscose rayon, which made it possible to obtain methylcellulose with a much higher degree of substitution than described in the literature [3] (Table 1).

TABLE 1

Molar concentration of diazomethane in ether solution	Time of methylation (in hours)	OCH_3-group content (%)	γ for the methylcellulose
0.34	43	14.23	79
0.51	24	22.5	131
0.50	24	16.75	95
0.50	20	17.4	99

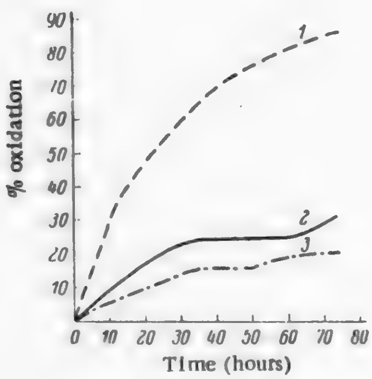
* 58th communication in the series "A Study of the Structure and Properties of Cellulose".

A reduction in the molar concentration of the diazomethane below 0.5, even when the time of methylation of the cellulose is considerably increased, leads to the formation of cellulose with a lower degree of substitution. The number of free primary hydroxyl groups in the methylcelluloses obtained was determined by tritylation and the number of free glycol groups by oxidation with periodic acid. The methylcellulose tritylation data show (Table 2) that in the methylation of cellulose with diazomethane the greater reactivity is likewise shown by the secondary hydroxyl groups, which confirms their greater acidic character.

TABLE 2

No. of specimen	γ for the methylcellulose	γ for the trityl ether of the methylcellulose	Number of OCH_3-groups on the C_6	Z*
1	79	84	16	1.97
2	95	81	19	2.00
3	99	78	22	1.75
4	131	72	28	1.84

The results of the periodic acid oxidation of the methylcelluloses studied are given in the form of curves in the Figure.



The oxidation of "included" viscose rayon (1) and methylcellulose with $\gamma = 99$ (2) and $\gamma = 131$ (3). Conditions: 0.05 M periodic acid solution, pH 4-4.1, temperature 20°.

A comparison of the results of the examination of the methylcellulose by tritylation and by periodic acid oxidation shows that the methoxy groups attached to the secondary carbon atom fraction are situated almost exclusively on one of these. In methylcellulose with $\gamma = 99$, 22 methoxy groups are situated on the C_6 and 77 on $C_{2,3}$ (Specimen 3, Table 2). If all the 77 methoxy groups were situated on one of the secondary carbon atoms, the number of free glycol groups (γ gl.) should equal 23; according to the oxidation data it equals 25 (Curve 2). Even for methylcellulose with $\gamma = 131$, the greater reactivity of one of the secondary hydroxyl groups is very clearly shown. The number of methoxy groups on the secondary carbon atoms is 103, the number of free glycol groups according to the oxidation data is 16; consequently there are 84 methoxy groups situated on one of the secondary carbon atoms and 19 on the other.

EXPERIMENTAL

The "included" viscose rayon was prepared by the method described earlier [2]. The diazomethane was prepared according to the method of [4].

The methylation of cellulose with diazomethane. 1 g of dry "included" viscose rayon was treated with 100 ml 0.5 M ethereal diazomethane solution containing 2.5 ml water at a temperature of ~2° for varying periods of time. The specimens of methylcellulose obtained were washed with ether, dried and analysed. The examination of the methylcellulose by tritylation and periodic acid oxidation was carried out as described in previous communications [1].

* Z – the ratio of the number of methoxy groups situated on the average on 1 secondary carbon atom to the number of methoxy groups on the primary carbon atom.

SUMMARY

1. The distribution of methoxy groups in methylcellulose prepared by methylating cellulose with diazomethane has been studied.

2. In the reaction of cellulose with diazomethane, the greatest reactivity is shown by the secondary hydroxyl groups. The number of methoxy groups attached on the average to 1 secondary carbon atom is approximately 2 times greater than the number of methoxy groups on a primary carbon atom.

3. The results of the determination of the number of free glycol groups by periodic acid oxidation show that the methoxy groups attached to the secondary carbon atom fraction are situated almost exclusively on one of the secondary carbon atoms.

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THE REACTION OF ALKYL HYPOCHLORITES WITH PHOSPHITES

K. A. Petrov and G. A. Sokolsky

The reactions of the esters of phosphorous acid with alkyl halides, hydrogen halides, cyanogen halides, halogens and acyl halides is of considerable theoretical and practical interest. Using these reactions it is possible to prepare the most varied materials: the esters of alkyl- and arylphosphinic acids, the esters of cyano- and alkylcyanophosphinic acids etc. [1]. The reactions of phosphorous esters with alkyl hypochlorites, sulfenyl chlorides and chloramines have not been described up to the present. Only recently a short communication was published on the reaction of sulfenyl chlorides with neutral phosphites [2]. These reactions, like the ones listed above, apparently result from the tendency of the phosphorous esters to add on various materials with the formation of unstable products which are capable of further reaction. In the present work a report is given of the results of a study of the reaction of alkyl hypochlorites with phosphites.

The experiments carried out have shown that alkyl hypochlorites react vigorously with neutral phosphites. In the reaction of ethyl hypochlorite with triethyl phosphite, in carbon tetrachloride solution, triethyl phosphate is formed in almost quantitative yield:

$$(C_2H_5O)_3P + C_2H_5OCl \rightarrow (C_2H_5O)_3PO + C_2H_5Cl.$$

The reaction of alkyl hypochlorites with phosphorous esters, like the reaction of halogens, cyanogen halides and alkyl halides, evidently leads to the formation of unstable tetraalkylphosphonium chlorides which decompose with the formation of alkyl halide and trialkyl phosphates. In the case where the phosphite is treated with alkyl hypochlorites of different alcohols from those whose residues are present in the phosphites, the phosphonium chlorides formed have different alkyl groups present. When these products decompose, different phosphates will be obtained, depending on which alkyl halide is split off. In order to examine the influence of the nature of the radicals on the decomposition of the phosphonium halides, a study was made of the reaction of ethyl hypochlorite with trimethyl and triphenyl phosphites. It was established that in the first case dimethylethyl phosphate is obtained and in the second case – triphenyl phosphate, while methyl chloride and ethyl chloride are split off respectively. Thus the decomposition of the phosphonium halide takes place with the removal of the alkyl radical with the lowest molecular weight. Alkyl hypochlorites also react vigorously with acid phosphites with the formation of the normal phosphate. Thus in the reaction of ethyl hypochlorite with diethyl phosphite in carbon tetrachloride solution, triethyl phosphate was obtained:

$$(C_2H_5O)_2POH + C_2H_5OCl \rightarrow (C_2H_5O)_3PO + HCl.$$

EXPERIMENTAL

The reaction of ethyl hypochlorite with triethyl phosphite. A solution of 2.4 g ethyl hypochlorite in 20 ml dry carbon tetrachloride was added slowly with stirring and cooling by ice to a solution of 4.9 g triethyl phosphite in 20 ml of the same solvent. The reaction took place with vigorous evolution of heat. When the addition was complete the solvent was distilled off and the residue fractionated. This yielded 4.4 g (82%) of triethyl phosphate with b.p. 211-213°, d_4^{20} 1.0756, n_D^{20} 1.4092. Literature data for triethyl phosphate: b.p. 215°, d_4^{19} 1.0725, n_D^{17} 1.4067.

The reaction of ethyl hypochlorite with trimethyl phosphite. 4.0 g of trimethyl phosphite and 2.6 g ethyl hypochlorite yielded 4.2 g (85%) of dimethyl ethyl phosphate with b.p. 201-203°, d_4^{20} 1.1784 (literature data b.p. 203.5° and d_0^0 1.1752).

The reaction of ethyl hypochlorite with triphenyl phosphite. A solution of 2.1 g of ethyl hypochlorite in 10 ml dry carbon tetrachloride was added slowly with stirring and cooling by ice to a solution of 8.1 g triphenyl phosphite in 30 ml of the same solvent. When addition was complete, the solvent was distilled off and the residue recrystallized twice from aqueous alcohol (1:1). This yielded 8.3 g (97%) of triphenyl phosphate with m.p. 44°. A mixture with triphenyl phosphate prepared from phosphorus oxychloride and phenol gave no melting point depression.

The reaction of ethyl hypochlorite with diethyl phosphite. A solution of 3.9 g ethyl hypochlorite in 20 ml dry carbon tetrachloride was added slowly at 35° to a solution of 6.7 g diethyl phosphite in 30 ml of the same solvent. When the addition was complete, dry air was passed through the cooled solution for 2 hours to remove the hydrogen chloride. The solvent was then distilled off and the residue fractionated. This yielded 6.6 g (74%) of triethyl phosphate with b.p. 210-212°, d_4^{20} 1.0778, n_D^{20} 1.4083.

SUMMARY

The reaction of alkyl hypochlorites with esters of phosphorous acid has been studied. It has been established that the reaction of alkyl hypochlorites with neutral and acid phosphites leads to the formation of neutral esters of phosphoric acid.

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THE REACTION OF N-CHLORAMINES WITH PHOSPHITES

K. A. Petrov and G. A. Sokolsky

The present communication is devoted to a study of the reaction of N-chloramines with the esters of phosphorous acid. It has been suggested, that in view of the great similarity in chemical properties of the compounds in question, this reaction should take place in the same way as the reactions of alkyl hypochlorites and alkyl sulfenyl chlorides, which have been described earlier [1,2]. The experiments carried out have confirmed our suggestion. For example, the reaction of diethylchloramine with triethyl phosphite gives the diethylamide of diethyl phosphoric acid while with trimethyl phosphite it gives the diethylamide of dimethyl phosphoric acid. The latter is not described in the literature.

$$(RO)_3P + R'_2NCl \rightarrow (RO)_3P\begin{smallmatrix} \diagup NR'_2 \\ \diagdown Cl \end{smallmatrix} \rightarrow (RO)_2P\begin{smallmatrix} \nearrow O \\ \diagdown NR'_2 \end{smallmatrix} + RCl$$

In the reactions described the addition product and the alkyl halide were not isolated. The intermediate product could be isolated in the reaction of diethylamine with triphenyl phosphite in ether solution with cooling:

$$(C_6H_5O)_3P + (C_2H_5)_2NCl \rightarrow [(C_6H_5O)_3P{-}N(C_2H_5)_2]Cl.$$

The triphenoxydiethylamidophosphonium chloride dissolves only in polar solvents, which agrees with its ionic structure; it is hygroscopic and is decomposed by water into triphenyl phosphate and diethylamine hydrochloride:

$$[(C_6H_5O)_3P{-}N(C_2H_5)_2]Cl + H_2O \rightarrow (C_6H_5O)_3PO + (C_2H_5)_2NH \cdot HCl.$$

When heated to 90-100° the phosphonium halide decomposes with the formation of triphenoxyphosphazoethyl and ethyl chloride:

$$[(C_6H_5O)_3P{-}N(C_2H_5)_2]Cl \rightarrow (C_6H_5O)_3P{=}NC_2H_5 + C_2H_5Cl.$$

Triphenoxyphosphazoethyl is a pale green crystalline substance, melting at 33-34°, soluble in many organic solvents. There are no descriptions of phosphazocompounds of the general type $(RO)_3P{=}NR$ in the literature. To obtain proof of the structure of the triphenoxyphosphazoethyl, it was hydrolyzed by heating with hydrochloric acid; triphenyl phosphate and monoethylamine hydrochloride were isolated:

$$(C_6H_5O)_3P{=}NC_2H_5 + HCl + H_2O \rightarrow (C_6H_5O)_3PO + C_2H_5NH_2 \cdot HCl.$$

Thus the reaction of dialkylchloramines with normal esters of phosphorous acid leads to the formation of trialkoxydialkylamidophosphonium chlorides. These adducts are stable when formed from aromatic phosphites. The stable phosphonium halides decompose with the formation of triarylphosphazoalkyls and the unstable ones decompose with the formation of esters of the dialkylamides of phosphoric acid. The reaction of N-chloramines with acid aliphatic phosphites is similar to the reaction of the latter with alkyl hypochlorites and with sulfenyl chlorides [1,2]. Thus the reaction of diethylchloramine with diethylphosphorous acid leads to the formation of the diethylamide of diethylphosphoric acid:

$$2\,(C_2H_5O)_2POH + 2\,(C_2H_5)_2NCl \rightarrow (C_2H_5O)_2PON(C_2H_5)_2 +$$
$$+ (C_2H_5O)_2POCl + (C_2H_5)_2NH \cdot HCl.$$

EXPERIMENTAL

The reaction of diethylchloramine with trialkyl phosphites. A solution of 0.1 mole diethylchloramine in 30 ml dry carbon tetrachloride was added slowly with stirring and cooling by ice to a solution of 0.1 mole of the phosphite in 30 ml of the same solvent. The reaction took place with vigorous evolution of heat and a precipitate was obtained. When the addition was complete the precipitate was filtered off, the solvent distilled and the residue fractionated in vacuo. The diethylamide of diethylphosphoric acid was obtained in 62% yield.

B.p. 116-119° (25 mm), d_4^{20} 1.0401, n_D^{20} 1.4318; literature data; b.p. 114-117° (25 mm). Found %: P 15.02; Calculated %: P 14.83.

The diethylamide of dimethylphosphoric acid was obtained in 65% yield.

B.p. 85-86° (8 mm), d_4^{20} 1.0740, n_D^{20} 1.4284. Found %: P 17.34; Calculated %: P 17.13.

The reaction of diethylchloramine with triphenyl phosphite. A solution of 14.7 g triphenyl phosphite in 50 ml dry ether was added slowly with stirring and cooling by ice to a solution of 5.1 g diethylchloramine in 20 ml dry ether; a white crystalline precipitate was obtained. When this had settled the ether was poured off and the residue washed three times with dry ether. 17.8 g (90%) of triphenoxydiethylamidophosphonium chloride was obtained. This was a fine white crystalline substance, soluble in acetonitrile, chlorobenzene, and nitrobenzene, insoluble in ether, benzene and carbon tetrachloride; very hygroscopic and decomposed by atmospheric moisture.

Found %: Cl 8.73, P 7.12; Calculated %: Cl 8.50, P 7.42.

The hydrolysis of triphenoxydiethylamidophosphonium chloride. A mixture of 17.5 g triphenoxydiethylamidophosphonium chloride, 10 ml water and 20 ml carbon tetrachloride was shaken vigorously for 15 minutes. On standing, the mixture separated into layers which were then isolated. The residue from the evaporation of the aqueous solution (the upper layer) was recrystallized twice from a mixture of alcohol and ether (1:5). 4.1 g (90%) diethylamine hydrochloride with m.p. 222-223.5° was obtained (literature data: m.p. 223°). A mixture with material prepared from diethylamine and hydrogen chloride gave no melting point depression. The residue from the evaporation of the carbon tetrachloride solution (the lower layer) was recrystallized

twice from aqueous alcohol (1:1). 12.1 g (91%) triphenyl phosphate with m.p. 44° was obtained (literature data: m.p. 44-45°). A mixture with material prepared by hydrolysis of triphenyldichlorophosphate gave no melting point depression.

The thermal decomposition of triphenoxydiethylamidophosphonium chloride. When 14.0 g triphenoxydiethylamidophosphonium chloride was heated in vacuo on an oil bath a crystalline substance distilled over. This was fractionated three times to yield 8.2 g (65%) of triphenoxyphosphazoethyl with b.p. 171-173° (2 mm) and m.p. 33-34°. Greenish colored crystals, soluble in organic solvents and insoluble in water. Found %: P 8.71; Calculated %: P 8.76.

The decomposition of triphenoxyphosphazoethyl with hydrochloric acid. When a mixture of 3.5 g triphenoxyphosphazoethyl and 30 ml hydrochloric acid (d 1.19) was boiled for half an hour it separated into layers. The mixture was cooled, shaken up with 15 ml carbon tetrachloride and the layers which formed were separated. The residue from the evaporation of the aqueous solution (the upper layer) was recrystallized twice from a mixture of alcohol and ether (1:5). 0.8 g of ethylamine hydrochloride with m.p. 108° was obtained (literature data: m.p. 109°). A mixture with material prepared from monoethylamine and hydrogen chloride gave no melting point depression. The residue from the evaporation of the carbon tetrachloride layer (the lower layer) was recrystallized twice from aqueous alcohol (1:1). 3.0 g triphenyl phosphate with m.p. 44° was obtained.

The reaction of diethylchloramine with diethyl phosphite. 10.6 g of diethylchloramine was added slowly to a solution of 12.6 g diethyl phosphate in 20 ml dry ether at 40-50°. When the addition was complete the precipitate was filtered off, washed three times with dry ether and recrystallized twice from a mixture of alcohol and ether (1:5). 4.1 g diethylamine hydrochloride with m.p. 221.5° was obtained. The ether extracts were combined and evaporated in vacuo in a current of dry air; the residue was fractionated three times in vacuo to give: 1) 5.9 g diethylchlorophosphate with b.p. 94-95° (18 mm) [literature data: b.p. 95° (18 mm)]; 2) 7.0 g of the diethylamide of diethylphosphoric acid with b.p. 115-117° (23 mm), Found %: P 14.67; Calculated %: P 14.83.

SUMMARY

The reaction of N-chloramines with esters of phosphorous acid has been studied. It has been established that dialkylchloramines react with neutral and acid aliphatic phosphites to form the esters of dialkylamides of phosphoric acid; dialkylchloramines react with neutral aromatic phosphites to form triaryloxyphosphazoalkyls.

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THE REACTIONS OF SULFENYL CHLORIDES WITH PHOSPHITES

K. A. Petrov, G. A. Sokolsky and B. M. Polees

The present communication is devoted to the reaction of sulfenyl chlorides with the esters of phosphorous acid; as mentioned earlier [1], there exists a short report on the only examples of this reaction [2]. It may be supposed that the reaction of sulfenyl chlorides with phosphites will be similar to the reaction of alkyl hypochlorites with phosphites. To obtain experimental confirmation of this hypothesis a study was made of the reaction of different sulfenyl chlorides with different esters of phosphorous acid. The reaction was carried out in solution in carbon tetrachloride or chloroform with stirring and cooling. Thus the reaction of ethylsulfenyl chloride with triethyl phosphite gave O-diethyl-S-ethyl phosphate in good yield:

$$(C_2H_5O)_3P + C_2H_5SCl \rightarrow \left[(C_2H_5O)_3P\begin{matrix} \diagup SC_2H_5 \\ \diagdown Cl \end{matrix}\right] \rightarrow (C_2H_5O)_2(C_2H_5S)PO + C_2H_5Cl.$$

Convincing confirmation that the reaction of sulfenyl chlorides with neutral phosphites leads to the formation of O, O, S -trialkyl phosphates with the thioether group which was present in the sulfenyl chloride, is provided by the reaction of β-chloroethylsulfenyl chloride with trimethyl and triethyl phosphites and of β-chloro-n-propylsulfenyl chloride with trimethyl phosphite. These reactions lead respectively to the formation of O-dimethyl-S-β-chloroethyl phosphate, O-diethyl-S-β-chloroethyl phosphate and O-dimethyl-S-β-chloro-n-propyl phosphate, which are not described in the literature. The substances prepared are colorless liquids with a faint odor of camphor, soluble in organic solvents and insoluble in water.

The sulfenyl chlorides react with alkyl halogenophosphites in exactly the same way as they do with normal esters of phosphorous acid. For example, the action of ethylsulfenyl chloride on ethyl dichlorophosphite, diethylchlorophosphite and diethyl fluorophosphite gave the previously unknown S-ethyl dichlorophosphate, S-ethyl-O-ethyl chlorophosphate and S-ethyl-O-ethyl fluorophosphate, while the reaction of β-chloroethylsulfenyl chloride on diethyl chlorophosphite gave S-β-chloroethyl-O-ethyl chlorophosphate:

$$\begin{matrix} RO \diagdown \\ X \diagup \end{matrix} P{-}Hal + R'{-}S{-}Cl \rightarrow \begin{matrix} R'{-}S \diagdown \\ X \diagup \end{matrix} P \begin{matrix} \diagup\!\!\!\!= O \\ \diagdown Hal \end{matrix} + R{-}Cl.$$

(where $X = OR$ or Cl, & $Hal = Cl$ or F)

S-Ethyl-O-ethyl fluorophosphate was also prepared by replacing the chlorine in S-ethyl-O-ethyl chlorophosphate by fluorine using antimony trifluoride. In the same way S-β-chloroethyl-O-ethyl fluorophosphate

and diethyl fluorophosphite were obtained from S-β-chloroethyl-O-ethyl chlorophosphate and diethyl chlorophosphite.

In the study of the reaction of alkylsulfenyl chlorides with aliphatic esters of phosphorous acid, the unstable intermediate products—the O,O,O,S-tetraalkylphosphonium chlorides — could not be isolated. It seemed probable that these substances would prove to be stable and would be isolable if they were formed from aromatic esters of phosphorous acid. In an attempt to isolate these compounds the reaction between ethylsulfenyl chloride and triphenyl phosphite was carried out in solution in carbon tetrachloride, ether, benzene and in the absence of solvent. In all cases, instead of the expected phosphonium chloride, triphenyl thiophosphate was obtained in almost quantitative yield:

$$(C_6H_5O)_3P + C_2H_5SCl \rightarrow (C_6H_5O)_3P{=}S + C_2H_5Cl.$$

On the basis of the data given, it may be concluded that in the phosphonium halides the R—S bond is stronger than the R—O bond but less strong than the Ar—O bond.

We made an attempt to overcome the difficulties encountered in obtaining stable addition products, by carrying out the reaction of aromatic sulfenyl chlorides with aromatic phosphites. In this case, too, however, the phosphonium chlorides could not be isolated. The reaction of p-nitrophenylsulfenyl chloride with triphenyl phosphite gave a yellow crystalline substance which proved to be p,p'-dinitrodiphenyldisulfide. A second product of the reaction was a viscous yellow-green oil with a sharp odor, which fumed in air and was decomposed with water to triphenyl phosphate. On distillation the oil decomposed to chlorobenzene and diphenyl chlorophosphate. On the basis of the hydrolytic and thermal decomposition of this second product it may be concluded that it is triphenoxyphosphonium dichloride. Thus the reaction of aromatic sulfenyl chlorides with phosphites takes place according to the following scheme:

$$(RO)_3P + 2ArSCl \rightarrow (RO)_3PCl_2 + ArSSAr.$$

The reaction of alkylsulfenyl chlorides with acid aliphatic phosphites is exactly similar to the reaction of the latter with alkyl hypochlorites [1]. Thus the reaction of ethylsulfenyl chloride with diethylphosphorous acid gives O-diethyl-S-ethyl phosphate. The properties of the substances obtained are given in Table 1.

TABLE 1

Formula	Yield (%)	Boiling point	d_4^{20}	n_D^{20}
$(C_2H_5O)_2(C_2H_5S)PO$ *	85	120—121° (18 мм)	1.1093	1.4538
$(CH_3O)_2(ClCH_2CH_2S)PO$	76	119 (4 мм)	1.2941	1.4952
$(C_2H_5O)_2(ClCH_2CH_2S)PO$ *	80	120 (4 мм)	1.2009	1.4837
$(CH_3O)_2(CH_3CHClCH_2S)PO$	78	121 (3 мм)	1.1212	1.4880
$C_2H_5SPOCl_2$	78	94—95 (17—18 мм)	1.4055	1.5153
$(C_2H_5O)(C_2H_5S)POCl$	84	98—99 (7—8 мм)	1.2265	1.4847
$(C_2H_5O)(C_2H_5S)POF$	66	70.5—71 (6 мм)	1.2120 **	—
$(C_2H_5O)(ClCH_2CH_2S)POCl$	70	131—133 (14—15 мм)	1.3779	1.5120
$(C_2H_5O)(ClCH_2CH_2S)POF$	76	131—133 (18 мм)	1.3581 ***	—
$(C_2H_5O)_2PF$	62	101—102	—	—
$(C_6H_5O)_3PS$ *	93	221—222 (4 мм) ****	—	—

* Substance described in the literature.

** d_0^0 given.

*** d_{20}^{20} given.

**** M.p. 47°.

EXPERIMENTAL

The reaction of alkylsulfenyl chlorides with trialkyl phosphites and alkyl halogenophosphites. A solution of 0.1 mole of the sulfenyl chloride in 30 ml dry carbon tetrachloride was added slowly with stirring and cooling by ice to a solution of 0.1 mole of the phosphite in 30 ml of the same solvent. The reaction took place with vigorous evolution of heat. When the addition was complete the solvent was distilled off and the residue fractionated in vacuo. The analysis data are given in Table 2.

TABLE 2

Formula	Calculated %			Found %		
	P	Cl	S	P	Cl	S
$(C_2H_5O)_2(C_2H_5S)PO$	15.66	—	16.47	15.43	—	16.36
$(CH_3O)_2(ClCH_2CH_2S)PO$	15.16	17.31	15.66	15.08	17.16	15.47
$(C_2H_5O)_2(ClCH_2CH_2S)PO$	13.33	15.22	13.76	13.31	15.60	13.51
$(CH_3O)_2(CH_3CHClCH_2S)PO$	—	16.25	14.64	—	16.42	14.79
$C_2H_5SFOCl_2$	17.31	39.67	17.88	17.31	39.45	17.67
$(C_2H_5O)(C_2H_5S)POCl$	16.44	18.83	16.97	16.28	18.71	16.76
$(C_2H_5O)(C_2H_5S)POF$	18.02	—	18.60	18.04	—	18.49
$(C_2H_5O)(ClCH_2CH_2S)POCl$	13.90	31.84	14.35	13.97	31.66	14.12
$(C_2H_5O)(ClCH_2CH_2S)POF$	15.02	17.19	15.50	14.78	16.96	15.27
$(C_2H_5O)_2PF$	22.14	—	—	21.95	—	—
$(C_6H_5O)_3PS$	9.06	—	—	8.95	—	—

The reaction of p-nitrophenylsulfenyl chloride with triphenyl phosphite. A solution of 3.5 g triphenyl phosphite in 10 ml chloroform was added slowly with stirring and cooling by ice to a solution of 4.3 g p-nitrophenylsulfenyl chloride in 15 ml dry chloroform; a crystalline precipitate separated and the solution became colorless. When the addition was complete the precipitate was filtered off and recrystallized twice from chloroform. 3.4 g (97%) p,p'-dinitrodiphenyl disulfide with m.p. 170-171° was obtained. A mixture with the product obtained from sodium sulfide and -nitrochlorobenzene gave no melting point depression. The solvent was distilled in vacuo from the filtrate. The residue—a thick light greenish liquid—was washed three times with dry benzene and ether. 4.2 g (97.5%) of triphenoxyphosphonium dichloride was obtained.

Distillation of the phosphonium dichloride yielded 1.2 g chlorobenzene with b.p. 130-130.5° and d_4^{20} 1.1083 and 2.9 g diphenyl chlorophosphate with b.p. 214-215° (20 mm); literature data for diphenyl chlorophosphate: b.p. 212-215° (21 mm).

Found %: Cl 13.58; 13.33. $C_{12}H_{10}O_3ClP$. Calculated %: Cl 13.22.

When moist air was passed through the triphenoxyphosphonium dichloride solution while the solvent was being distilled off, 3.6 g of a white crystalline substance was obtained. Two recrystallizations from aqueous alcohol (1:1) yielded triphenyl phosphate with m.p. 44°. A mixture with a product prepared from phosphorus oxychloride and phenol gave no melting point depression.

The reaction of ethylsulfenyl chloride with diethyl phosphite. A solution of 2.9 g ethylsulfenyl chloride in 20 ml dry CCl_4 at 40 - 50° was added slowly to a solution of 4.2 g diethyl phosphite in 20 ml of the same solvent. When the addition was complete, dry air was passed through the cooled solution for 2 hours to remove hydrogen chloride. The solvent was then distilled off and the residue fractionated in vacuo. 4.6 g (76%) of S-ethyldiethyl phosphate was obtained.

B.p. 118-121° (19 mm), d_0^0 1.1253, n_D^{20} 1.4624. Literature data for S-ethyldiethylphosphate: b.p. 122° (20 mm) and d_0^0 1.1245.

The reaction of chlorophosphates and chlorophosphites with antimony trifluoride. An equimolecular mixture of sublimed, finely divided antimony trifluoride and diethyl chlorophosphite or S-ethyl-O-ethyl chlorophosphate or S-β-chloroethyl-O-ethyl chlorophosphate was heated at 60° for 15 minutes with vigorous stirring. The fluorides formed were then distilled from the reaction mixture and fractionated.

SUMMARY

The reaction of sulfenyl chlorides with esters of phosphorous acid has been studied. It has been established that alkylsulfenyl chlorides react with neutral and acid alkyl phosphites and alkyl halogenophosphites to form S-alkyl-O-alkyl phosphates and S-alkyl-O-alkyl halogenophosphates respectively. Alkylsulfenyl chlorides react with neutral aromatic phosphites to form O-aryl thiophosphates. Arylsulfenyl chlorides react with neutral aromatic phosphites to form arylphosphonium dichlorides and disulfides.

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SYNTHESIS IN THE PHENOTHIAZINE SERIES

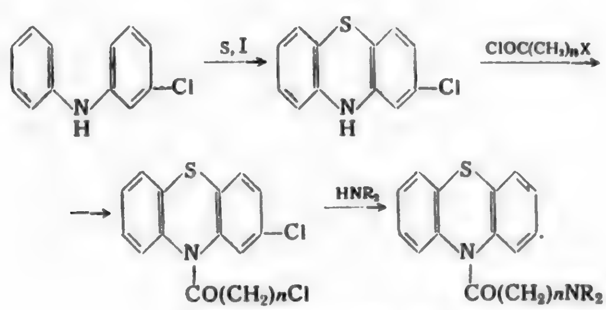
I. THE SYNTHESIS OF DIALKYLAMINOACYL-2-CHLOROPHENOTHIAZINES

S. V. Zhuravlev and A. N. Gritsenko

Reports have appeared in the literature in recent years on the high therapeutic activity of certain derivatives of chlorophenothiazines containing a dialkylaminoalkyl chain on the nitrogen atom [1-4]. The compound of this group which has attracted most attention from doctors and pharmacologists is 10-dimethylaminopropyl-2-chlorophenothiazine [1], known in France as "RP 4560" or largactil. This substance was tested and found use in other countries under the same or other names (chlorpromazin, megaphen) [5-7]. In the Soviet Union this substance came into medical practice under the name of aminazin [8].

Largactil is a new neuroplegic agent for narcosis and treatment of neurological disorders. The high therapeutic activity and varied effect on the organism of largactil and other phenothiazine derivatives led us to prepare certain dialkylaminoacyl derivatives of 2-chlorophenothiazine for pharmacological tests. It is known that certain alkylamino- and dialkylaminoacyl derivatives of phenothiazine and their quaternary salts show antihistamine activity together with other interesting pharmacological properties [9-12].

With this aim we undertook the synthesis of 10-dialkylaminoacyl derivatives of 2-chlorophenothiazine which was carried out according to the following scheme:



($n = 1, 2, 5$; $X = Cl, Br$; $R = CH_3, C_2H_5$)

The original 2-chlorophenothiazine was prepared by the reaction of 3-chlorodiphenylamine with sulfur in the presence of iodine by heating at a temperature of 160-165° until the evolution of hydrogen sulfide ceased. The isomeric 4-chlorophenothiazine obtained in this reaction was separated by crystallization of the products from aqueous acetone and then from chloroform. The 10-halogenoacyl-2-chlorophenothiazines were obtained in 42.2-87.2% yield in a similar way to the halogenosubstituted derivatives of phenothiazine [9] by the action of the chlorides of the corresponding halogenoacids on 2-chlorophenothiazine in benzene solution. When a solution of the halogenoacylphenothiazines in benzene or toluene was heated with 2.5 mole of

dimethylamine or diethylamine, the 10-dialkylaminoacyl substituted 2-chlorophenothiazines were obtained. The dimethylamine was added in 27% alcohol solution and the reaction carried out in a closed tube. The reaction with diethylamine was carried out at atmospheric pressure. Only 10-(α-diethylaminocaproyl)-2-chlorophenothiazine was prepared by the reaction of 10-(α-bromocaproyl)-2-chlorophenothiazine and diethylamine in benzene solution in a closed tube. In this case the yield was considerably higher and the product purer than when the reaction was carried out in the usual conditions.

The dialkylaminoacyl derivatives of 2-chlorophenothiazine, apart from 10-(α-dimethylaminoacetyl)-2-chlorophenothiazine, were isolated and characterized by us in the form of their hydrochlorides, since the bases were not sufficiently stable in air; 10-(α-dimethylaminoacetyl)-2-chlorophenothiazine proved to be sufficiently stable both as the hydrochloride and as the base. We have prepared: 1) 10-(α-chloroacetyl)-, 10-(β-chloropropionyl)-, and 10-(α-bromocaproyl)-2-chlorophenothiazines, which are white crystalline substances, readily soluble in organic solvents and insoluble in water; 2) the hydrochlorides of 10-(α-diethylaminoacetyl)-, 10-(β-diethylaminopropionyl)-, 10-(α-diethylaminocaproyl)-, 10-(α-dimethylaminoacetyl)-, 10-(β-dimethylaminopropionyl)-, 10-(α-dimethylaminocaproyl)-2-chlorophenothiazines—crystalline substances readily soluble in water. The tests on the compounds obtained were carried out in the pharmacology department by Yu. I. Vikhlyaev and I. G. Chugunov (Director—Prof. V. V. Zakusov). Preliminary data provide evidence that the hydrochlorides of dialkylaminoacyl -2-chlorophenothiazines exhibit antihistamine properties. In comparison with the same compounds containing no chlorine atom in position 2 of the phenothiazine ring, however, their antihistamine activity is shown more weakly. The greatest antihistamine activity is shown by the hydrochloride of 10-(dimethylaminoacetyl)-2-chlorophenothiazine.

EXPERIMENTAL

The preparation of 2-chlorophenothiazine. A mixture of 45 g m-chlorodiphenylamine, 14.1 g sulfur and 0.22 g iodine was heated on an oil bath at 160-165° until the evolution of hydrogen sulfide ceased. When cooled to room temperature the reaction product was obtained as a solid yellow colored lump with m.p. 165-168° and dissolved in boiling acetone. When it had dissolved, water was added to the solution until a turbidity appeared, followed by active charcoal, and heating continued for a further 30 minutes. 49 g of material separated after standing overnight in a refrigerator. After filtration and drying it melted at 175-180°. M.p. 194-196° after two recrystallizations from chloroform. According to the data in [1], 2-chlorophenothiazine has m.p. 196-197°. Yellowish colored crystalline powder, readily soluble in chloroform, acetone, benzene and dichloroethane, less readily in alcohol, insoluble in water.

Found %: N 6.16, 6.09. $C_{12}H_8NSCl$. Calculated %: N 6.03.

The synthesis of 10-halogenoacyl-2-chlorophenothiazines. 10-(α-Chloroacetyl)-2-chlorophenothiazine. 11.7 g 2-chlorophenothiazine in 50 ml benzene was boiled for 2 hours on a water bath with 8.5 g chloroacetyl chloride. When the benzene was distilled off the oily residue crystallized. It was first carefully ground with methanol, filtered off and dried. 13.56 g (87.2%) of dry material was obtained with m.p. 108-110°. After two recrystallizations from methanol it melted at 117-118° and was readily soluble in chloroform, ether and hot methanol, moderately soluble in cold methanol, insoluble in water.

Found %: N 4.45, 4.45; Cl 22.76, 22.86. $C_{14}H_9ONSCl_2$. Calculated %: N 4.51; Cl 22.86.

10-(β-Chloropropionyl)-2-chlorophenothiazine. 26.5 g 2-chlorophenothiazine in 125 ml benzene was boiled for 5 hours with 23.3 g β-chloropropionyl chloride. The benzene and excess β-chloropropionyl chloride were distilled off in vacuo. The semi-solid mass which separated on cooling was stirred well with ether, filtered off and washed with ether. 15.4 g (42.2%) of crystalline material with m.p. 97-98° was obtained. When recrystallized from 80% isopropyl alcohol, it melted at 105-106°. The substance was readily soluble in benzene, carbon tetrachloride and acetone, soluble with difficulty in methanol, insoluble in water.

Found %: N 4.21, 4.39; Cl 21.57, 21.67. $C_{15}H_{11}ONSCl_2$. Calculated %: N 4.32; Cl 21.87.

10-(α-Bromocaproyl)-2-chlorophenothiazine. 15.8 g 2-chlorophenothiazine in 75 ml benzene was heated for 8 hours with 17.1 g α-bromocaproyl chloride. The solvent was distilled off and the oily residue dissolved in alcohol and heated for 30 minutes with active charcoal. The alcohol solution was filtered and on cooling

yielded 21.9 g (79%) of material with m.p. 115-117°. After two recrystallizations from acetone it melted at 124-125°, and was readily soluble in chloroform, moderately soluble in alcohol and ether.

Found %: N 3.69, 3.68. $C_{18}H_{17}ONSClBr$. Calculated %: N 3.41.

The synthesis of 10-dialkylaminoacyl-2-chlorophenothiazines. 10-(α-Diethylaminoacetyl)-2-chlorophenothiazine. 4.2 g 10-(α-chloroacetyl)-2-chlorophenothiazine in 20 ml toluene was boiled for 1.5 hours with 2.34 g diethylamine. The diethylamine hydrochloride which precipitated was filtered off and the toluene and excess diethylamine were distilled off in vacuo. The oily residue was treated with 5% hydrochloric acid and then with active charcoal. When the filtered solution was made strongly alkaline an oil separated which was extracted with ether and the ether solution dried with magnesium sulfate. This ether solution was treated with an ether solution of hydrogen chloride to yield a solid precipitate which was recrystallized from alcohol with ether. M.p. 180° (with decomp.); yield 3.22 g 60%. The substance was readily soluble in water.

Found %: N 7.12, 7.21; Cl 18.67, 18.58. $C_{18}H_{20}ON_2SCl_2$. Calculated %: N 7.30; Cl 18.50.

10-(β-Diethylaminopropionyl)-2-chlorophenothiazine was prepared in a similar manner to that in the previous example. 6.5 g 10(β-chloropropionyl)-2-chlorophenothiazine and 3.75 g diethylamine in 30 ml benzene yielded 4.0 g (50%) of the hydrochloride of 10-(β-diethylaminopropionyl)-2-chlorophenothiazine, which after solution in alcohol and precipitation with ether had m.p. 162-164°.

Found %: N 7.24, 7.20; Cl 18.24, 18.17. $C_{19}H_{22}ON_2SCl_2$. Calculated %: N 7.05; Cl 17.85.

10-(α-Diethylaminocaproyl)-2-chlorophenothiazine. 6.16 g 10-(α-bromocaproyl)-2-chlorophenothiazine and 3 g diethylamine in 25 ml benzene were heated for 12 hours in a closed tube on a boiling water bath. The oil which remained after removal of the excess diethylamine and solvent was treated with dilute hydrochloric acid to yield a solid precipitate which was filtered off and washed with acetone. 5.4 g (82%) of material was obtained. After three recrystallizations from acetone, it melted at 187-188° (with decomp.), and dissolved readily when heated in alcohol, acetone and water.

Found %: N 6.35; Cl 15.45. $C_{22}H_{28}ON_2SCl_2$. Calculated %: N 6.38; Cl 16.14.

10-(α-Dimethylaminoacetyl)-2-chlorophenothiazine. 7.75 g 10-(α-chloroacetyl)-2-chlorophenothiazine and 2.93 g (10.85 g, 27% alcohol solution) of dimethylamine in 25 ml benzene were heated for 4 hours in a closed tube on the water bath. The hydrochloride was isolated as in the previous experiment by making the solution alkaline with 30% caustic soda, and converted to the base, with m.p. 93-100°. Weight 7 g (83%). After two recrystallizations from alcohol, it melted at 99-100°; readily soluble in most organic solvents.

Found %: N 8.44; Cl 11.01. $C_{16}H_{15}ON_2SCl$. Calculated %: N 8.78; Cl 11.12.

Hydrochloride: m.p. 211° (with decomp.), soluble in water.

10-(β-Dimethylaminopropionyl)-2-chlorophenothiazine. 6.5 g 10-(β-chloropropionyl)-2-chlorophenothiazine and 2.24 g dimethylamine in 25 ml benzene were heated for 4 hours in a tube; the precipitate obtained after treatment with dilute hydrochloric acid was filtered off. 7 g (95%) of hydrochloride with m.p. 156-157° was obtained. The melting point did not change after a second crystallization from alcohol with ether.

Found %: N 7.23; Cl 18.55. $C_{17}H_{18}ON_2SCl_2$. Calculated %: N 7.58; Cl 19.23.

10-(α-Dimethylaminocaproyl)-2-chlorophenothiazine. 6.16 g 10-(α-bromocaproyl)-2-chlorophenothiazine and 1.78 g dimethylamine were heated with 20 ml benzene for 20 hours. 4.0 g (65%) of hydrochloride with m.p. 125-128° was obtained. After two recrystallizations from acetone it melted at 180° (with decomp.).

Found %: N 6.62; Cl 17.44. $C_{20}H_{24}ON_2SCl_2$. Calculated %: N 6.81; Cl 17.24.

SUMMARY

Several dialkylaminoacyl derivatives of 2-chlorophenothiazine have been prepared.

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THE DIRECT AMINATION OF BENZOTHIAZOLE DERIVATIVES

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An extensive literature is devoted to the amination of heterocyclic compounds containing nitrogen [1]. The most widely adopted methods for amination are the action of alkali metal amides and the action of hydroxylamine. Sodamide, which was first suggested for amination by Chichibabin [2], gives good yields in the amination of pyridine and quinoline. The amination of benzothiazole with sodamide in quinoline yields three reaction products—2-aminobenzothiazole, dibenzothiazole and bis-o-aminophenyl disulfide [3]. Hydroxylamine has been used as an aminating agent chiefly for aromatic compounds [4,5]. According to the data available, the reaction takes place in good yield in those cases where the molecule of the compound being aminated contains a hydrogen atom with increased reactivity. Skraup has used hydroxylamine for the amination of benzothiazole [6]. He obtained 2-aminobenzothiazole in 92% yield by heating benzothiazole with an equimolecular amount of hydroxylamine hydrochloride and dilute alkali for 2 hours.

Since the hydrogen in position 2 of benzothiazole derivatives with substituents in the benzene nucleus is extremely reactive, it might be supposed that benzothiazole derivatives, too, could be aminated by the action of hydroxylamine. This is particularly important for the synthesis of 2-aminobenzothiazoles with substituents in the 5-position, for the preparation of which the universal method of cyclization of arylthioureas is not always applicable, since in the cyclization of meta-substituted arylthioureas the formation of 5- and 7-derivatives of 2-aminobenzothiazoles is possible, and the yield of the 5-substituted compound is often low. Thus, for example, in the cyclization of m-tolylthiourea the yield of 2-amino-5-methylbenzothiazole is 13%; the same product has been prepared by us by the amination of 5-methylbenzothiazole in 68% yield [7].

In the present work a study has been made of the possibility of aminating benzothiazoles containing different substituents in the 5-position: NH_2, NO_2, COOH and $COOC_2H_5$. It turned out that methyl-, methoxy- and carboxybenzothiazoles were aminated in good yield; nitro- and carbethoxybenzothiazoles could not be aminated, either in the conditions described above or by carrying out the reaction in alcohol solution.

EXPERIMENTAL

Starting materials. 5-Nitrobenzothiazole was prepared according to the method described in [8]. Starting from 2-bromo-5-nitroaniline, the authors prepared 1-formylamino-2-bromo-5-nitrobenzene with m.p. 191° (yield 62%). By changing the method of separating the product we succeeded in raising the yield and obtaining the product in a purer condition. The reaction was carried out in the following way: 6.4 g 2-bromo-5-nitroaniline and 65 ml 85% formic acid were heated under reflux on a boiling water bath for 3 hours. The mixture was cooled and the crystals which separated were filtered off, washed with formic acid and then with water. Yield 6.5 g (89%), m.p. 201-202°. A further 0.25 g was obtained from the mother liquor after evaporation to half bulk. Total yield 92%. After recrystallization from alcohol—long colorless needles, m.p. 202-203°. The 1-formylamino-2-bromo-5-nitrobenzene was converted to 5-nitrobenzothiazole by the action of a solution of sodium sulfide in alcohol [9].

5-Aminobenzothiazole was prepared by reduction of 5-nitrobenzothiazole with stannous chloride in hydrochloric acid [8]. Spieler and Prijs [8] decomposed the double salt so obtained with hydrogen sulfide and obtained 5-aminobenzothiazole hydrochloride. They did not separate the free base. We decomposed the double

salt with dilute alkali and when the alkaline solution was cooled to +10° the 5-aminobenzothiazole crystallized out. After recrystallization from water—colorless needles, m.p. 76°. Yield 60%. The product contained a molecule of water of crystallization which was split off by heating to 70° for several hours.

Found %: N 16.42, 16.47; H_2O 10.27. $C_7H_6N_2S$. Calculated %: N 18, 67. $C_7H_6N_2S \cdot H_2O$. Calculated %: N 16.67; H_2O 10.71.

5-Carboxybenzothiazole was prepared by oxidizing 5-methylbenzothiazole with potassium permanganate (for the synthesis of 5-methylbenzothiazole see [7]). After recrystallization from water—colorless needles, m.p. 261-262°, yield 41% calculated on the methylbenzothiazole which had reacted (part of the methylbenzothiazole was recovered).

Found %: N 8.00, 8.15. $C_8H_5O_2NS$. Calculated %: N 7.82.

5-Carboxybenzothiazole is readily soluble in alcohol and glacial acetic acid, soluble with difficulty in water, insoluble in benzene and ether.

5-Carbethoxybenzothiazole was obtained by boiling a solution of 5-carboxybenzothiazole with anhydrous alcohol and a catalytic amount of sulfuric acid. Yield 72%. After crystallization from dilute alcohol—colorless needles, m.p. 106-108°.

Found %: N 6.71, 6.83. $C_{10}H_9O_2NS$. Calculated %: N 6.76.

5-Carbethoxybenzothiazole is readily soluble in alcohol and ether, slightly soluble in cold benzene, soluble in boiling benzene and boiling water.

The amination. A mixture of equal quantities of the 5-substituted benzothiazole and hydroxylamine hydrochloride with an equivalent amount of dilute alkali was boiled under reflux. The time of heating depended on the substituent in the benzene ring: with the amino group, half an hour was enough, with the carboxyl group, 4 hours were required, while with the nitro- and carbethoxy-groups the reaction did not take place even on prolonged heating. The precipitate was filtered off after cooling. In the case of 5-carboxy-benzothiazole the free acid was separated beforehand from its sodium salt by acidifying with acetic acid, avoiding an excess of the latter. The product was then crystallized. The results of the reaction are given in the Table.

TABLE

Starting material	Reaction product	Melting point	Yield (%)
5-Methylbenzothiazole	2-Amino-5-methylbenzothiazole	171-172°	68 [7]
5-Aminobenzothiazole	2,5-Diaminobenzothiazole	175	72
5-Nitrobenzothiazole	5-Nitrobenzothiazole	Did not react	
5-Carboxybenzothiazole	2-Amino-5-carboxybenzothiazole	>300°(decomp.)	64
5-Carbethoxybenzothiazole	5-Carbethoxybenzothiazole	Did not react	

As can be seen from the data in the Table, the amination of 5-aminobenzothiazole led to the formation of 2,5-diaminobenzothiazole. After crystallization from water with charcoal or from benzene—colorless needles, m.p. 175°, yield 72%. According to the literature data, m.p. 175° [10].

Found %: N 24.16, 24.28. $C_7H_7N_3S$. Calculated %: N 25.43.

The amination of 5-carboxybenzothiazole gave 2-amino-5-carboxybenzothiazole (yield 64%), which decomposed on heating above 300°. The product was soluble in alcohol, ethylene glycol and hot water, slightly soluble in cold water, benzene and ether. A solution of 2-amino-5-carboxybenzothiazole in ethylene glycol gave a bright orange coloration with aqueous calcium hypochlorite solution. The ethyl ester of 2-amino-5-benzothiazolecarboxylic acid was prepared for analysis. After recrystallization from dilute alcohol—colorless grains, m.p. 200-201°.

Found %: N 12.44, 12.37. $C_{10}H_{10}O_2N_2S$. Calculated %: N 12.60.

5-Carbethoxybenzothiazole and 5-nitrobenzothiazole remained unchanged on heating in the conditions described or in alcohol solution.

SUMMARY

1. The reaction of 5-substituted benzothiazoles with hydroxylamine hydrochloride has been studied. 5-Amino- and 5-carboxybenzothiazole are aminated by this treatment in the 2-position. 5-Nitrobenzothiazole and 5-carbethoxybenzothiazole do not react with hydroxylamine.

2. The following new derivatives of benzothiazole have been prepared: 5-aminobenzothiazole, 5-carboxybenzothiazole, 5-carbethoxybenzothiazole, 2-amino-5-carboxybenzothiazole and 2-amino-5-carbethoxybenzothiazole.

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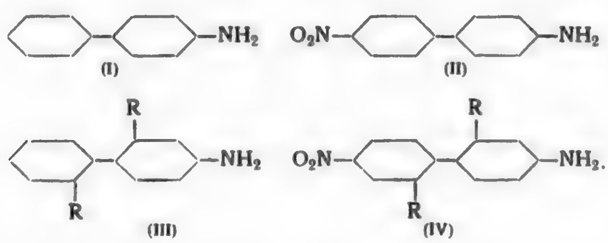
SPATIAL STRUCTURE AND REACTIVITY

V. INHIBITED INTERNAL ROTATION AND THE KINETICS OF THE ACYLATION OF 2,2'-HALOGEN DERIVATIVES OF 4-AMINODIPHENYL AND 4-AMINO-4'-NITRODIPHENYL

L. M. Litvinenko and A. P. Grekov

In previous communications in this series [1-3], devoted to a study of the kinetics of the acylation of certain amino derivatives of diphenyl, we have shown that the interaction between the groups NO_2 and NH_2 in the molecule of 4-amino-4'-nitrodiphenyl is weakened as a result of the introduction, into the 2,2'-positions of the molecule, of substituents which limit the internal rotation of the phenyl nuclei. Recently [3] we found a convenient method for evaluating quantitatively the influence of steric factors on the reactivity of substances similar to the above. To achieve this, a comparison is made of the kinetic data for the reactions of the following series of compounds under identical conditions:



If it is assumed that the electronic influence of all the substituents on the reactivity of the amino group in the diphenyl derivatives does not deviate to any great extent from additivity [3], then the ratio of the rate constants for the acylation of these materials

$$F = \frac{k_{I}}{k_{II}} : \frac{k_{III}}{k_{IV}},$$

which we have called "the steric conjugation reduction factor", should indicate the extent to which the influence of the nitro group on the amino group via the diphenyl system is reduced as a result of the steric action of the substituent R, which weakens the conjugation of the benzene rings in the given system.

The aim of the present work was to establish the connection between spatial configuration and reactivity in a series of aminonitroderivatives of diphenyl containing halogen atoms in the 2,2'-positions. To achieve

this a comparison has been made of our earlier results [2,3] from the kinetic study of the acylation of 4-amino-diphenyl (I) and 4-amino-4'-nitrodiphenyl (II) with p-nitrobenzoyl chloride in benzene solution with the data now obtained on the kinetic study of the reaction (in similar conditions) between the same chloride and the halogen-containing diphenyl derivatives represented by formulae (III) and (IV), where R= Cl and Br. For a fuller comparison of the results of this and the previous experiments, a study was also made of the kinetics of the acylation of m-chloroaniline and m-bromoaniline.

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The preparation and purification of the starting materials. The benzene and p-nitrobenzoyl chloride were purified in the same way as described in previous work [1]. The synthesis and methods of purification of the halogen-containing amines, derivatives of diphenyl, have been described by us in a separate communication [4]. The m-chloroaniline was recrystallized several times in the form of the sulfate from 10% H_2SO_4, the salt decomposed with aqueous ammonia, the base dried with solid KOH and distilled repeatedly in vacuo. The m-bromoaniline was prepared by reduction of m-bromonitrobenzene [5] in methanol solution with hydrazine hydrate in the presence of Raney nickel.* The amine was purified in the same way as m-chloroaniline. The physical constants of the halogen derivatives of aniline agreed well with the literature data.

Method of measuring reaction rates and experimental results. The reaction between aromatic amines and the chlorides of carboxylic acids in an inert solvent takes place in two stages

$$RCOCl + ArNH_2 \rightarrow RCONHAr + HCl,$$
$$ArNH_2 + HCl \rightarrow ArNH_2 \cdot HCl.$$

The process may be expressed by the following overall equation:

$$RCOCl + 2ArNH_2 \rightarrow RCONHAr + ArNH_2 \cdot HCl.$$

The considerably slower first stage determines the second order of the complete reaction. In accordance with the equations given above, the solutions were prepared so that the concentration of the amine in the mixture of reacting substances was always exactly twice the concentration of the chloride. In the present work the method used for determining the reaction rate was a further improvement on the method worked out by us earlier [7] which involved stopping the reaction at a definite time by pouring a solution of ammonia in methanol into the mixture of reacting substances, and after evaporation of the organic solvent determining the unreacted amine in the residue by potentiometric titration with sodium nitrite using a control platinum electrode [8]. We later found that the presence of a small amount of residual methanol in the sample being analyzed often made the titration of the amine more difficult, since the potential jump in a number of cases was insufficiently sharp. We give below the improved method for the measurement of reaction rates in the acylation of aromatic amines with acid chlorides, which may also be used in the study of the analogous reactions of acid anhydrides.

Equal volumes of the working solutions [1] of the chloride and amine in benzene** were added to a long-necked flask and glass tube with ground stopper respectively, at 20° in such amount that 0.1 mmole of amine (corresponding to 10 ml 0.01 N sodium nitrite) and 0.05 mmole of chloride were present in the mixture of

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* Balcom and Furst [6], who suggested this general method for the reduction of nitro compounds, recommend that the reaction be carried out in ethanol. We have found that it takes place equally well in methanol.

** In the present case 10 ml 0.005 M chloride solution and 0.01 M amine solution were used in all the experiments.

reacting substances at the initial moment, irrespective of the original concentration of the materials taking part in a given reaction. When these solutions had been maintained at the required temperature in a thermostat (10 minutes) the amine was added rapidly to the chloride solution. In order that the quantity of solution leaving the tube equalled the required volume (in this case exactly equal to the volume of chloride solution), the amine solution was added, not to a dry tube, but to a tube from which the same volume of amine solution had previously been poured at the temperature of the thermostat. After a definite time interval from the start of the reaction, 2 ml of a solution consisting of one volume of anhydrous diethylamine and three volumes of benzene was added to the mixture, as a result of which the chloride which had not yet reacted combined immediately with the diethylamine. After 3-5 minutes, one drop of 0.1% methyl red solution in glacial acetic acid was added to the solution and dilute (1:3) hydrochloric acid added gradually to the mixture with vigorous shaking until weakly acid (avoid excess!). The reaction flask was connected to a descending condenser and all the organic solvent distilled off by immersing the flask as completely as possible in a hot water bath. The aqueous residue was poured into a 50 ml beaker and the walls of the flask washed several times with small portions of glacial acetic acid, the amount of which was determined by the solubility of the amine hydrochloride. Potassium bromide and several drops of hydrochloric acid were added to the beaker as described in the analysis method [8], and the determination of the aromatic amine carried out. Control experiments showed that the dissolved diethylamine and methyl red present in the mixture being analyzed did not react with nitrous acid in the conditions under which the analysis was carried out,* and therefore have no influence on the accuracy of the determination of the aromatic amine.** It was also found from control experiments that the diethylamine does not displace the aromatic amine from the amide produced in the course of the acylation, since even when the mixture is acidified 40 minutes after the addition of the diethylamine, the calculated rate constants are practically unchanged.

Before each series of experiments it was considered advisable to check the reliability of the prepared working solutions of chloride and amine, and to achieve this, in addition to carrying out the necessary preliminary analyses of these solutions, we kept a mixture of the reacting components, either in the molecular ratio 1:2 or with a somewhat higher quantity of amine, at a high temperature for a sufficient period of time to ensure that the reaction was known to be complete. In this case the amine not combined as amide should be titrated quantitatively within the limits of error, which indicates a 100% yield for the reaction and the absence of side reactions.

A comparison of parallel experiments carried out for the reactions previously studied by us, using the present method and the previous method [7], showed a completely satisfactory agreement in the data; in the new method, however, the analytical part is much more clearly reproducible.

The rate constants were calculated according to the formula:

$$k = \frac{1}{2\beta t}\left(\frac{1}{a-x} - \frac{1}{a}\right),$$

Where a and x are the initial concentration and the decrease in initial concentration respectively (in moles per liter), t is the time in seconds and β is a correction for the thermal expansion of benzene from 20° to the temperature of the experiment [1]. This formula is obtained after some modification of the usual formula for a reaction of the second order if it is taken into consideration that the concentration of the amine is exactly double the chloride concentration and that two molecules of amine leave the sphere of reaction with every molecule of chloride. The measurement of the reaction rate was carried out at 25° and 50°. The evaluation of the accuracy of the calculated values of the rate constants was made as before [1,8] using the methods of mathematical statistics [9] (reliability 0.95).

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*Dimethylamine and piperidine, like diethylamine, do not react with nitrous acid in the conditions described, and may be used if necessary for the same purpose with equal success.

**It must be certain at the start of the work that the materials and solvents used do not contain impurities capable of reacting with nitrous acid, and the appropriate control tests to establish this must be carried out.

The energy of activation and the pre-exponential factor from the Arrhenius equation were calculated according to the formulas:

$$E = \frac{4.575\,T_1 T_2}{T_2 - T_1} \log\frac{k_2}{k_1}\,,$$

$$\log PZ = \log k + \frac{E}{4.575\,T}\,.$$

From the equation for the value of the rate constant derived from the theory of the activated complex and suitably modified for reactions in solutions [10], the working formula for the calculation of the entropy of activation is obtained:

$$\Delta S^{\#} = -49.19 + 4.575 \log\frac{k}{T} + \frac{E}{T}\,.$$

The values given for PZ and $\Delta S^{\#}$ are mean values obtained by substituting in turn both values of the absolute temperature and the corresponding rate constants in (3) and (4) and using the unrounded value of E to calculate both PZ and $\Delta S^{\#}$. The numerical data obtained are given in Tables 1-6, where the following symbols are used: t_i—time intervals after which the rate measurements were made; k_i—mean value of the rate constant for a given time interval for a number of measurements n_i; k—the same for all Σn_i measurements. In the second column in Tables 1-6 are given the mean values of the reaction yield for n_i measurements. In Table 7 are given the chief data on the kinetics of the reactions studied in the present work, and also the values of some quantities from the reactions studied by us earlier. The experiments repeated with a number of substances (4-amino-2,2'-dichlorodiphenyl, 4-amino-4'-nitro-2,2'-dibromodiphenyl) after 5-7 months gave results which practically coincided.

TABLE 1

The Kinetics of the Reaction of 4-Amino-2,2'-dichlorodiphenyl with p-Nitrobenzoyl Chloride ($a = 0.0025$)

25°				50°			
t_i (min)	Yield (%)	k_i $\frac{\text{liter}}{\text{mole sec}}$	n_i	t_i (min)	Yield (%)	k_i $\frac{\text{liter}}{\text{mole sec}}$	n_i
50	15.4	0.0122	3	20	16.4	0.0339	2
80	23.4	0.0128	3	40	28.9	0.0351	2
120	33.7	0.0142	3	65	41.4	0.0375	3
180	46.1	0.0159	3	100	54.6	0.0414	2
360	56.3	0.0120	3				
$k_{25°} = 0.0134 \pm 0.0009$				$k_{50°} = 0.0370 \pm 0.0022$			

$E = 7800\ \frac{\text{cal}}{\text{mole}}$ $PZ = 6.7 \cdot 10^{3}\ \frac{\text{liter}}{\text{mole sec}}$ $\Delta S^{\#} = -43.1\ \frac{\text{cal}}{\text{deg mole}}$

TABLE 2

The Kinetics of the Reaction of 4-Amino-4'-nitro-2,2'-dichlorodiphenyl with p-Nitrobenzoyl Chloride ($a = 0.0025$)

25°				50°			
t_i (min)	Yield (%)	k_i $\frac{\text{liter}}{\text{mole sec}}$	n_i	t_i (min)	Yield (%)	k_i $\frac{\text{liter}}{\text{mole sec}}$	n_i
180	9.5	0.00196	3	120	17.6	0.00617	3
300	16.0	0.00213	4	180	25.3	0.00650	3
480	23.6	0.00216	3	300	37.2	0.00681	3
720	31.8	0.00217	4	480	51.7	0.00771	3
960	36.6	0.00202	3	720	61.7	0.00772	2

$k_{25^\circ} = 0.00209 \pm 0.00004$ $\qquad$ $k_{50^\circ} = 0.00693 \pm 0.00037$

$$E = 9200 \frac{\text{cal}}{\text{mole}} \quad PZ = 11.2 \cdot 10^{3} \frac{\text{liter}}{\text{mole sec}} \quad \Delta S^{\ne} = -42.1 \frac{\text{cal}}{\text{deg mole}}$$

TABLE 3

The Kinetics of the Reaction of m-Chloroaniline with p-Nitrobenzoyl Chloride ($a = 0.0025$)

25°				50°			
t_i (min)	Yield (%)	k_i $\frac{\text{liter}}{\text{mole sec}}$	n_i	t_i (min)	Yield (%)	k_i $\frac{\text{liter}}{\text{mole sec}}$	n_i
50	26.1	0.0237	2	20	28.4	0.0684	2
80	33.7	0.0213	2	65	54.7	0.0641	3
120	40.3	0.0189	2	100	65.8	0.0664	2
180	53.1	0.0211	2	150	74.1	0.0659	3
360	68.5	0.0203	2				

$k_{25^\circ} = 0.0211 \pm 0.0015$ $\qquad$ $k_{50^\circ} = 0.0660 \pm 0.0021$

$$E = 8700 \frac{\text{cal}}{\text{mole}} \quad PZ = 5.3 \cdot 10^{4} \frac{\text{liter}}{\text{mole sec}} \quad \Delta S^{\ne} = -39.0 \frac{\text{cal}}{\text{deg mole}}$$

TABLE 4

The Kinetics of the Reaction of 4-Amino-2,2'-dibromodiphenyl with p-Nitrobenzoyl Chloride ($a = 0.0025$)

25°				50°			
t_i (min)	Yield (%)	k_i $\frac{\text{liter}}{\text{mole sec}}$	n_i	t_i (min)	Yield (%)	k_i $\frac{\text{liter}}{\text{mole sec}}$	n_i
50	20.9	0.0177	2	10	12.7	0.0502	2
80	28.4	0.0166	2	20	20.7	0.0451	2
120	39.8	0.0185	2	40	35.7	0.0479	2
180	51.3	0.0196	2	65	48.2	0.0495	2

$k_{25^\circ} = 0.0181 \pm 0.0011$ $\qquad$ $k_{50^\circ} = 0.0482 \pm 0.0023$

$$E = 7500 \frac{\text{cal}}{\text{mole}} \quad PZ = 5.7 \cdot 10^{9} \frac{\text{liter}}{\text{mole sec.}} \quad \Delta S^{\ne} = -43.4 \frac{\text{cal}}{\text{deg. mole}}$$

TABLE 5

The Kinetics of the Reaction of 4-Amino-4'-nitro-2,2'-dibromodiphenyl with p-Nitrobenzoyl Chloride ($a = 0.0025$)

25°				50°			
t_1 (min)	Yield (%)	k_1 $\frac{\text{liter}}{\text{mole sec}}$	n_1	t_1 (min)	Yield (%)	k_1 $\frac{\text{liter}}{\text{mole sec}}$	n_1
180	13.9	0.00300	3	120	22.3	0.00825	2
360	23.7	0.00290	3	180	30.6	0.00844	3
480	29.5	0.00293	3	240	41.8	0.01032	2
900	44.8	0.00303	3	480	54.7	0.00868	2
				720	68.0	0.01020	3
$k_{25°} = 0.00297 \pm 0.00011$				$k_{50°} = 0.0920 \pm 0.00068$			

$$E = 8700 \frac{\text{cal}}{\text{mole}} \quad PZ = 6.6 \cdot 10^{3} \frac{\text{liter}}{\text{mole sec}} \quad \Delta S^{\#} = -43.1 \frac{\text{cal}}{\text{deg mole}}$$

TABLE 6

The Kinetics of the Reaction of m-Bromoaniline with p-Nitrobenzoyl Chloride ($a = 0.0025$)

25°				50°			
t_1 (min)	Yield (%)	k_1 $\frac{\text{liter}}{\text{mole sec}}$	n_1	t_1 (min)	Yield (%)	k_1 $\frac{\text{liter}}{\text{mole sec}}$	n_1
50	23.9	0.0211	2	20	27.2	0.0646	2
80	30.2	0.0181	2	40	41.0	0.0600	3
120	39.6	0.0183	2	65	50.0	0.0531	2
180	52.0	0.0202	2	150	69.4	0.0523	2
360	64.5	0.0169	2				
$k_{25°} = 0.0189 \pm 0.0012$				$k_{50°} = 0.0578 \pm 0.0035$			

$$E = 8600 \frac{\text{cal}}{\text{mole}} \quad PZ = 3.6 \cdot 10^{4} \frac{\text{liter}}{\text{mole sec}} \quad \Delta S^{\#} = -39.8 \frac{\text{cal}}{\text{deg. mole}}$$

DISCUSSION OF RESULTS

A comparison of the rates of acylation of aniline and 4-aminodiphenyl (Table 7) on the one hand, and of their halogen derivatives on the other, shows that the halogen atoms situated in the meta-position relative to the aromatic amino group bring about a very real change in the reactivity of this group by exerting a powerful electron-accepting action. If it is taken that the phenyl group, which is a para-substituent in the benzene nucleus and exerts a very powerful electron-accepting action, has almost no influence on the reactivity of the aromatic amino group [2], then from a comparison of the rate constants of 4-amino-2,2'-dibromodiphenyl and m-bromoaniline it may be concluded that the influence of the bromine atom situated in the second benzene ring of the amino derivative of diphenyl (position 2') on the reactivity of the amino group in the first ring is practically negligible. We see the same in the similar carbomethoxy amino derivatives [3]. There is a more real difference in the rates of acylation, however, between the analogous chlorine-containing derivatives of benzene and diphenyl. The reason for this difference in the case of the chlorine-containing compounds apparently lies in the fact that in the chlorine derivative of 4-aminodiphenyl there is a marked deviation from additivity in the influence of several substituents on the reactivity of the aromatic amino group [3].

TABLE 7

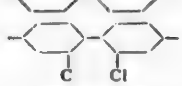
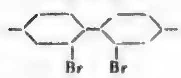
Collated Data on the Kinetics of the Acylation of Amines with p-Nitrobenzoyl Chloride.•

Amine	$k_{25°}$	$k_{50°}$	E	PZ	$\Delta S^{\#}$
4-Aminodiphenyl••	0.533 ± 0.010	1.11 ± 0.02	5600	$7.1 \cdot 10^{3}$	—42.8
4-Amino-4'-nitro-diphenyl••	0.0505 ± 0.0011	0.118 ± 0.003	6500	$2.9 \cdot 10^{3}$	—44.7
4-Amino-2,2'-dichlorodiphenyl	0.0134 ± 0.0009	0.0370 ± 0.0022	7800	$6.7 \cdot 10^{3}$	—43.1
4-Amino-4'-nitro-2,2'-dichlorodiphenyl	0.00209 ± 0.00004	0.00693 ± 0.00037	9200	$11.2 \cdot 10^{3}$	—42.1
m-Chloroaniline	0.0211 ± 0.0015	0.0660 ± 0.0021	8700	$5.3 \cdot 10^{4}$	—39.0
4-Amino-2, 2'-dibromodiphenyl	0.0181 ± 0.0011	0.0482 ± 0.0023	7500	$5.7 \cdot 10^{3}$	—43.4
4-Amino-4'-nitro-2,2'-dibromodiphenyl	0.00297 ± 0.00011	0.00920 ± 0.00068	8700	$6.6 \cdot 10^{3}$	—43.1
m-Bromoaniline	0.0189 ± 0.0012	0.0578 ± 0.0035	8600	$3.6 \cdot 10^{4}$	—39.8
Aniline•••	0.580 ± 0.018	—	—	—	—

Table 8 gives the values of the factor F for the systems of the unsubstituted diphenyl and its 2,2'-halogen derivatives. It is seen from the data in this Table that the conjugation between the aromatic nuclei in the diphenyl derivatives substituted in the 2,2'-positions by halogen atoms is noticeably weakened by comparison with the diphenyl system without 2,2'-substituents. The introduction into the 2,2'-positions of the diphenyl molecule of chlorine atoms, or of bromine atoms, leads to an identical steric effect, which has a somewhat lower magnitude than the effect brought about in the analogous case by the carbomethoxy groups ($F_{25°} = 2.71$; $F_{50°} = 2.67$), which is most probably explained by the high polarity of these groups and not by their volume effect [12].

TABLE 8

Values of the Factor F for the Systems of Diphenyl and its 2,2'- Dihalogen Derivatives

System	$F_{25°}$	$F_{50°}$
	1	1
	1.65	1.76
	1.73	1.80

• The dimensions of the quantities are the same as in Tables 1-6.

•• Data taken from the works [2,3].

••• $k_{25°}$ was calculated from the value for $k_{30°}$ given in Table 2 of paper [7] (the value given there for $k_{30°} = 0.69$ is inaccurate, the figure 0.683 being more correct), using a value for E equal to 5900 cal/mole [11].

From the fact that the rate constants for the acylation of 4-amino-4'-nitro-2,2'-dihalodiphenyls are several times lower than the corresponding constants for the 4-amino-2,2'-dihalodiphenyls, it may be concluded that there is a clearly defined interaction between the NO_2 and NH_2 groups situated in different benzene rings, even under the conditions of steric hindrance, caused by the halogen atoms, i.e. the conjugation between the aromatic nuclei in the 2,2'-dihalogen derivatives of diphenyl being considered, although weakened for this reason, is not completely destroyed. With reference to the question of how the reactions studied in the present work may be characterized by bringing in the energy data, we limit ourselves meanwhile to pointing out that the reactions described, like those studied by us earlier [1-3] take place with very low values of the energy and entropy of activation.

SUMMARY

1. A study has been made of the kinetics of the acylation of 4-amino-2,2'-dichlorodiphenyl, 4-amino-4'-nitro-2,2'-dichlorodiphenyl, m-chloroaniline and the bromine-containing analogs of these compounds by p-nitrobenzoyl chloride in benzene solution.

2. It has been shown that the presence, in the 2,2'-positions of the diphenyl molecule, of halogen atoms, which cause steric hindrance to the internal rotation of the aromatic nuclei of this molecule and alter its geometric configuration, brings about a considerable weakening of the interaction of the NO_2 and NH_2 groups in the 4-amino-4'-nitro-2,2'-dihalodiphenyl molecules by comparison with 4-amino-4'-nitrodiphenyl. A quantitative estimation has been made of the steric influence of halogen atoms in the 2,2'-positions leading to a decrease in the conjugation of the aromatic rings in the molecules of diphenyl derivatives.

3. A more satisfactory method for studying the reaction kinetics of the acylation of aromatic amines with acid chlorides than that described earlier has been given.

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A NEW WAY OF INTRODUCING A DIHYDROXYACETONE SIDE-CHAIN

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A dihydroxyacetone side-chain in position 17 of the steroid molecule is a necessary structural unit of the so-called glucocorticoids (cortisone, Reichstein's substance F, hydrocortisone); hence its introduction into the steroid molecule is one of the steps in the synthesis of cortisone. Definite interest also lies in simpler compounds with dihydroxyacetone chains, as cortisone analogs, although, it is true, very distant ones.

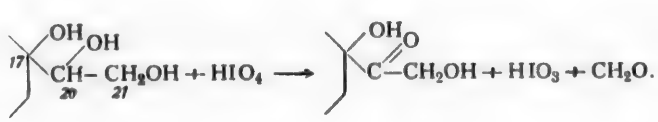
The methods of introducing the dihydroxyacetone chain into steroid compounds may be divided into two groups— building up the dihydroxyacetone chain in pre-existing compounds, i.e., when there is a β-acetyl group in position 17, and formation of the dihydroxyacetone chain in 17-keto steroids by adding 2 carbon atoms to the steroid.

Classic examples of the first group of methods are the synthesis of cortisone by Gallagher et al. [1], and the synthesis of Reichstein's substance S by Julian et al. [2]. An important example of the second group of syntheses is the reaction between 17-keto steroids and organo-magnesium compounds or acetylene. The side-chain then assumes the "unnatural" α-configuration, since the following stages involve reactions which destroy the asymmetric center at C_{17} (dehydrogenation of allyl rearrangement). An excellent review of methods for introducing dihydroxyacetone chains is given in Nazarov and Bergelson's monograph [3].

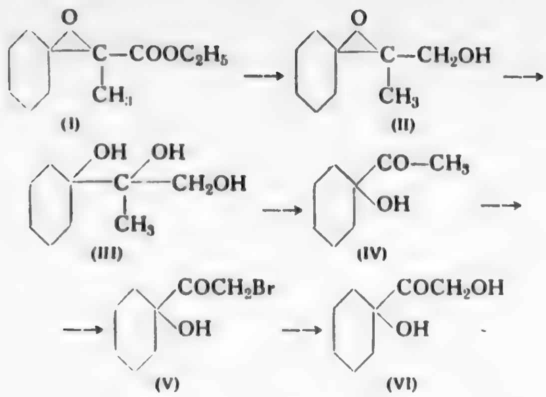
Using the observations made earlier by one of us [4] that glycidol esters can be reduced to the corresponding glycides while maintaining the α-epoxy ring, we investigated whether it was possible to introduce pentamethylene chains into 17-keto steroid molecules via the Darsens-Klaisen glycide synthesis.

The model synthesis we set out here starts from cyclohexanone, which is condensed with the α-chloropropionic ester in the presence of sodium ethoxide (after Darsens), this giving the ethyl ester of α-methyl β-β-pentamethyleneglycidic acid (I). We were successful in reducing the carboethoxy group in (I) with lithium aluminum hydride at minus 65-70° without breaking the α-epoxy ring, thereby getting the 2-methyl-3, 3-pentamethylene-glycide (II). The latter was treated with 2% acetic acid at room temperature, giving 2-methyl-1, 1-pentamethyleneglycerol, (III). Thus a glycerol side-chain was introduced, which could be further transformed to the dihydroxyacetone one as required. On treating (III) with $NaIO_4$ we got 1-acetyl-cyclohexanol-1 (IV).

It is known from the literature [5] that on treating steroid compounds with glycerol side-chains in position 17 with periodic acid, rupture occurs between positions 20 and 21, and the corresponding hydroxy-ketone and formaldehyde are formed:



Further, using dihydroxyacetone we got the bromide (V) which was washed with alkali in aqueous tert-butanol to give 1-hydroxyacetyl-1-cyclohexanol (VI); the acetate of (VI) was made by acetylating it with acetic anhydride in pyridine.



EXPERIMENTAL

Ethyl ester of α-methyl-β,β-pentamethyleneglycidic acid, (I). In a 3-necked flask fitted with a stirrer, an inverted condenser and a thermometer, were placed 24.5 g of cyclohexanol, 42.5 g of the ethyl ester of 2-chloropropionic acid, and 100 ml of dry benzene. The mixture was cooled to -5°C, and 34 g of dry powdered sodium ethoxide were added from a hopper over two hours with vigorous stirring, the hopper being closed by a stopper and joined to the flash by a piece of rubber tube.* While the sodium ethoxide was being added, the temperature of the reaction mixture was not allowed to rise above 10°C. When all the sodium ethoxide had been added, stirring was continued for 4 hours and after standing for 48 hours the yellow-brown mass was heated on a boiling water bath for 3 hours. On cooling the reaction mixture water separated. The upper layer was removed and the lower extracted twice with benzene. The combined benzene solutions were washed with water, a 3% solution of acetic acid, and water, after which they were dried over anhydrous sodium sulfate, the solvent was distilled off, and the glycide ester distilled in vacuo. 46.8 g were obtained (94.5%) of the ethyl ester of α-methyl β,β-pentamethyleneglycidic acid. B. p. 127-129° (19 mm). According to literature data the b. p. of the glycidic ester is 154-156° (40 mm) [6].

2-Methyl-3,3-pentamethyleneglycide (II). In a 4-neck flask, fitted with a stirrer sealed with mercury, an inverted condenser, a dropping funnel and a thermometer, and isolated from atmospheric water vapor by calcium chloride tubes, was placed a solution of 9.9 g of the ethyl ester of α-methylpentamethylene-glycidic acid in 50 ml of dry ether. The mixture was cooled to minus 65-70°, and then 1.1 g of 95% aluminum lithium hydride in 16 ml of absolute ether were added drop by drop over 2 - 2.5 hours with vigorous stirring. The temperature of the reaction mixture was kept at minus 65-70°, and then gradually raised to -30°, maintained at this figure for 1 hour and then further raised to -10°; 4 ml of ethyl acetate (to decompose the excess aluminum lithium hydride) was then added, 30 ml of a saturated solution of ammonium chloride, and a few milliliters of water. The ether layer was separated, the water layer being extracted with fresh ether. After drying the ether solution and removing the solvent the residual oil was distilled in vacuo. 6.6 g (84.6%) of 2-methyl-3,3-pentamethyleneglycide was obtained.

B.p. 125° (17 mm), n_D^{20} 1.4800, d_4^{20} 1.038, MR_D 42.70; Calc. 42.53.
Found %: C 69.01, 69.05; H 10.12, 10.18 · $C_9H_{16}O_2$. Calculated %: C 69.19; H 10.32.

2-Methyl-1,1-pentamethyleneglycerol (III). To 2.7 g of 2-methyl-3,3-pentamethyleneglycide were added 80 ml of a 2% solution of acetic acid, and the reaction mixture was stirred at room temperature for 1 hour, the substance being by then almost completely dissolved. The reaction mass was then extracted with ether: the 2-methyl-1,1-pentamethyleneglycerol which remained dissolved in the water was obtained as colorless crystals after distilling off the water in vacuo: m.p. 97-98°; amount 1.81 g (60%).

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* The sodium ethoxide was made by dissolving sodium metal in a 20-fold excess of dry alcohol, the excess being later distilled off; the solid ethoxide was dried for 20-30 minutes at 160° (12 mm), cooled to room temperature, rapidly powdered and rapidly used in the reaction.

Found %: C 62.56, 62.29; H 10.29, 10.21. $C_9H_{18}O_3$. Calculated %: C 62.04; H 10.41.

1-Acetyl cyclohexanol (IV). To 4.3 g of 2-methyl-1,1-pentamethyleneglycerol in a small amount of water was added 135 ml of a 0.2M solution of $NaIO_4$. The mixture was kept at room temperature for $1\frac{1}{2}$ hours, and then carefully extracted with ether. The ether solution was washed with a dilute solution of sodium bicarbonate, dried over anhydrous magnesium sulfate, and after removing the ether the substance was distilled in vacuo. 2.75 g (77.7%) of 1-acetylcyclohexanol-1 was obtained. B. p. 83-84° (10 mm).

Found %: C 67.44, 67.07; H 9.69, 10.07. $C_8H_{14}O_2$. Calculated %: C 67.57; H 9.92.

The semicarbazone of 1-acetylcyclohexanol-1 made in the usual way, gave a m. p. of 208-209°.

Found %: N 21.41, 21.53. $C_9H_{17}O_2N_3$. Calculated %: N 21.10.

The literature date are [7,8]: b.p. of 1-acetylcyclohexanol-1 90-93° (15 mm); m.p. of the semicarbazone 208-209°.

The water layer remaining after ether extraction was treated with a saturated solution of dimedone. After some while a deposit was formed, which after recrystallizing from alcohol melted at 188-189°, and gave no depression of the m.p. in a test with a known specimen of formyldimedone.

1-Bromoacetylcyclohexanol-1 (V). To make the dioxane dibromide a mixture of 1.4 ml of dioxane and 1.5 ml of heptane (cooled with ice) had added to it a cooled solution of 2.88 g (0.92 ml) of bromine in 2.9 ml of heptane, with stirring. The reaction mass was stirred for 5 minutes, being cooled in an ice bath. The precipitated orange deposit was filtered off, washed with 2 lots of 1.6 ml of heptane, and dried in vacuo. The dioxane dibromide was used at once in the bromination reaction (it decomposes very rapidly). Yield 2.9 g.

To a solution of 1.63 g of 1-acetylcyclohexanol-1 in 10 ml of ether was added an ether solution of 2.9 g of dioxane dibromide with rapid stirring. The solution became dark brown. After complete decolorization, which took 20 minutes, the ether solution was washed with water, a 5% solution of sodium bicarbonate, and dried over heated sodium sulfate. After removing the ether 2.5 gm of a yellowish liquid were obtained.

To identify the 1-bromoacetylcyclohexanol-1 the quarternary pyridinium salt was prepared. To 0.55 g of the bromide was added 0.23 g of pyridine, the mixture was heated to 60°C for 5 minutes and then kept at 0°C for several hours. The crystalline substance dissolved in methanol and was precipitated by ether. After a few re-precipitations a substance of m.p.147-148° was obtained.

Literature data: m.p. 148° [8].

1-Hydroxyacetylcyclohexanol-1 [8] (VI). To 1.95 g of 1-bromoacetylcyclohexanol-1 in 4 ml of tert.-butanol was added 5 ml of a saturated solution of sodium chloride, and with vigorous stirring 0.42 g of caustic potash in 5 ml of water, in 10 separate portions. The neutralization of each portion was checked with phenolphthalein. After the final addition of the alkali the mixture was acidified with dilute sulfuric acid, the water layer was saturated with sodium chloride and the tert.-butanol layer was separated, and the water layer was re-extracted with chloroform. The solutions were dried with sodium sulfate, and the solvents distilled off in vacuo. The substance obtained crystallized on cooling. 0.6 g of 1-hydroxyacetylcyclohexanol-1 was obtained. After recrystallizing from light petroleum ether the m.p. was 88-88.5°.

Literature data: m.p. of 1-hydroxyacetylcyclohexanol-1 88-89° [8].

Found %: C 61.01, 60.63; H 9.13, 8.99. $C_8H_{14}O_3$. Calculated %: C 60.73; H 8.92.

1-Acetoxyacetylcyclohexanol-1 [8]. 0.42 g of 1-hydroxyacetylcyclohexanol-1 was acetylated with acetic anhydride in dry pyridine for 16 hours; 0.46 g of 1-acetoxyacetylcyclohexanol-1 was obtained.

The semicarbazone of the dihydroxyketone acetate was made by adding to a solution of 0.46 g of the acetate in 5 ml of aqueous pyridine 0.97 g of the hydrochloride of semicarbazide. The solution was left overnight in a refrigerator at 0°. 0.29 g of the semicarbazone of 1-acetoxyacetylcyclohexanol-1 was obtained which had a m.p. of 170°-171° after a few recrystallizations from water.

Literature data: m.p. of the semicarbazone of 1-acetoxyacetylcyclohexanol-1 is 171-172° [8].

Found %: C 51.37, 51.45; H 7.57, 7.51; N 16.05, 16.54. $C_{11}H_{19}O_4N_3$. Calculated %: C 51.35; H 7.40; N 16.35.

SUMMARY

Using cyclohexanone, a new way of introducing dihydroxyacetone chains into keto-steroids has been found, this being based on the preparation of the glycide ester (after Darsens), reduction of the carboethoxyl groups of the ester to the alcohol while maintaining the α-epoxy ring, opening the epoxy ring, giving the glycerol derivative, oxidizing this with periodic acid to the ketone, and introducing an additional hydroxyl group by bromination and hydrolysis.

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FREE RADICAL REACTIONS IN SOLUTIONS

VII. ROLE OF ACTIVATORS IN THE DECOMPOSITION PROCESSES IN TRIAZENES AND IN INITIATION OF POLYMERIZATION

V. Ya. Andakushkin, B. A. Dolgoplosk and I. I. Radchenko

Diazoaminobenzene and some of its homologs were first proposed as polymerization initiators for divinyl and isoprene in homogenous media by Byzov [1]. The initiating action of aromatic diazoamino compounds in polymerization was assigned to their instability and tendency to tautomeric change. In 1936 Balandina et al [2] used aromatic diazoamino compounds to produce polymerization in emulsions. Before long, one of us, in collaboration with others, worked out the conditions under which the polymerization process was activated by diazoaminobenzene in the presence of water and activators (reducing agents) took place as an oxidation-reduction process via free radical stages.

Since the composition of the product formed was extremely complex, due to the development of secondary processes in which the aromatic diazo compounds took part, it was not possible to explain the mechanism by which the triazenes decomposed, and the role of the added activators, from the composition of the products in a reliable fashion.

We have earlier shown [3] that the alkyl aromatic triazenes decompose in the water phase at low temperatures, when the process involves the direct participation of the water, and the formation of free radicals during the intermediate stages of the reaction.

The present communication presents the results of some work on the role of activators in the decomposition processes of alkyl-aromatic triazenes and in the polymerization process.

Role of Activators in the Decomposition of Alkyl-Aromatic Triazenes

Various organic and inorganic compounds were used as activators in the decomposition of the alkyl-aromatic triazenes. Among the inorganic reducing agents, we studied sodium sulfite and ferrous sulfate, the organic ones being glucose, hydroquinone, ascorbic acid and some others. The most effective activator actions occurred in the pH range from 5 to 9.

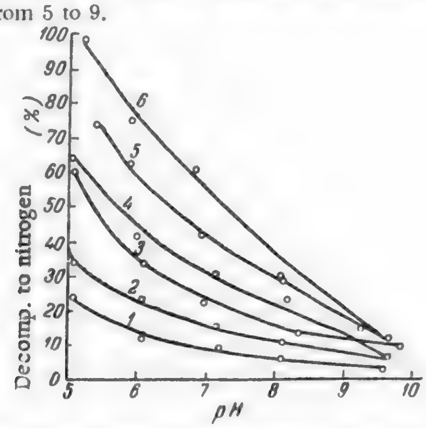

Fig. 1. Effect of activators on the decomposition of methyl phenyl triazene at varied pH values in the medium (50°C, 5 hours). 1) No activator; 2) glucose; 3) hydroquinone; 4) Na_2SO_3; 5) $FeSO_4$; 6) ascorbic acid.

Figures 1 and 2 show the curves which illustrate the decomposition of methyl and butylphenyltriazene in benzene emulsions due to the various materials given above at different pH values. In the experiments with sodium sulfite and glucose in acid media, hydrochloric acid was used to attain the desired pH; in the experiments with hydroquinone the hydrochloric acid was added in cases where the pH was less than 5.5. In all other cases the pH was adjusted by adding the appropriate amount of alkali.

As regards their effectiveness in the decomposition of triazenes the activators can be arranged in the following series: ascorbic acid > ferrous sulfate > sodium sulfite > hydroquinone > glucose.

In addition to the compounds given, substances of a weakly acid character also had an accelerator action, if they had no reducing properties but could be hydrolyzed,e. g. aluminum and ferric sulfates. Salts which could not be hydrolyzed(the sulfates or chlorines of the alkalis) had no such effects on the kinetics of the triazene decompositions or on the polymerization process.

The majority of the substances we studied (ascorbic acid, hydroquinone, hydroxycarbonyl compounds, ferrous salts etc.) had reducing properties under the conditions in which the process was carried out. The only exceptions were ferric and aluminum sulfates. As regards the ion salts it may be supposed that a reaction develops which is characteristic of many oxidation - reduction systems, as follows:

$$Fe^{+++} \xrightarrow{+DH_2} Fe^{++},$$

where DH_2 is aniline or some other product formed in the decomposition of the triazenes.

The reaction may then develop as with hydroperoxides or with hydrogen peroxide:

$$R{-}N{=}NOH + Fe^{++} \longrightarrow R. + N_2 + OH^- + Fe^{+++}.$$

Such assumptions are quite ruled out in the case of aluminum salts.

We determined the content in the system of ascorbic acid, ferrous and ferric sulfate, and hydroquinone after the complete decomposition of methylphenyltriazene in water at 20°C, and in benzene emulsions at 50° and 60° C. The analyses were based on iodometric methods, since these compounds or the products of their oxidation, react with iodine or hydrogen iodide according to stoichiometric equations. The suitability of these methods was first checked under model conditions. The analytical data are given in Tables 1-4.

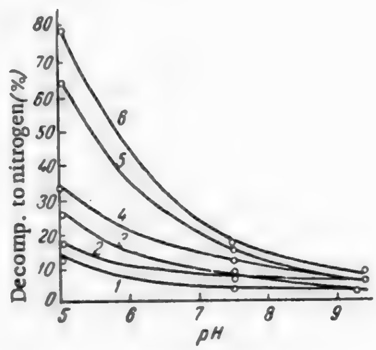

Fig. 2. Effect of activators on the decomposition of butyl phenyl triazene at different pH values in the medium (50°C, 5 hours). 1) No activator; 2) glucose; 3) hydroquinone; 4) Na_2SO_3; 5) $FeSO_4$; 6) ascorbic acid.

TABLE 1

Content of Ascorbic Acid After Decomposition of Methylphenyltriazene in Water and Benzene Emulsion.

Medium	Initial molar ratio of triazene: ascorbic acid	pH	Temp.	Ascorbic acid (in % of amount added)
Water	less triazene	2.68	20°	99.7
	" "	4.35	20	99.4
	1 : 1	3.3	20	93.8— 95.5
	2 : 1	3.47	20	94.8—101.2
	4 : 1	3.76	20	96.5— 97.5
	8 : 1	4.11	20	100.3
Benzene emulsion	less triazene	6.11	50	98.5
	1 : 1	5.03	50	94.1
	1 : 1	6.11	50	92.4
	2 : 1	4.08	50	99.5—100.5
	1 : 1	6.08	60	98.0—103.0

TABLE 2

Content of Hydroquinone in the System After Decomposition of Methylphenyltriazene (pH ~ 6.0)

Medium	Initial molar ratio, triazene: hydroquinone	Temp.	Hydroquinone found (in % of the amount added)
Water	less triazene	20°	99.7—101.3
	1 : 1	20	97.2—103.2
	2 : 1	20	99.3
Benzene emulsion	less triazene	50	100.2
	2 : 1	50	99.6—100.0
	1 : 1	60	94.9— 96.7

TABLE 3

Ferrous Iron Content in the System After Decomposition of Methylphenyltriazene (pH ~ 5.5)

Medium	Initial molar ratio of triazene: Fe^{++} (sulfate)	Temp.	Fe^{++} found (in % of the amount added)
Water	less triazene	20°	97.1
	1 : 1	20	99.3—100.0
	4 : 1	20	101.2
	10 : 1	20	98.4
Benzene emulsion	less triazene	50	97.4
	1 : 1	50	97.2— 99.4

TABLE 4

Ferric Iron Content in the System After Decomposition of Methylphenyltriazene (pH ~ 4.5)

Medium	Initial molar ratio of triazene: Fe^{++} (sulfate)	Temp.	Fe^{+++} found (in % of the amount added)
Water	less triazene	20°	100.0
	1 : 1	20	95.7—98.3
Benzene emulsion	less triazene	50	101.7
	1 : 1	50	101.5

It is clear from the data given in Tables 1-4 that the activators undergo practically no change in the decomposition of the triazenes, no matter what the amount of triazene added, or the nature of the medium and the temperature of the experiment. On this basis we can conclude that the increased rate of decomposition of the alkyl-aromatic triazenes in the presence of activators is not due to oxidation - reduction reactions, as in the case when peroxides and hydroperoxides are used [4,5], but is due to their catalytic action. The use of these activators is also without effect on the composition of the products from decomposition of the triazenes. The main products from the decomposition of methylphenyltriazene in an aqueous medium, whether activators are present or absent, were aniline and methanol, in addition to the nitrogen (Table 5).

Initiation of Polymerization

Under conditions where they decompose thermally (80–100°) the alkyl-aromatic triazenes initiate polymerization processes in styrene and other compounds in a homogenous medium. The triazene decompositions, which occur at much lower temperatures when water and activators are present, may be used to initiate polymerization processes in emulsion media. Table 6 gives the data which show the relation between the extent of polymerization and the amounts of triazenes added. In these experiments the polymerization was carried out in the absence of activators and at pH values close to 7.0.

The data given illustrate triazene initiation action in polymerization processes. When benzoquinone is introduced into the system the triazene decomposes more rapidly, but the polymerization process is completely suppressed, which is due to the benzoquinone reacting quantitatively with the free radicals [6].

TABLE 5

Composition of the Products Formed When Methylphenyltriazene Decomposes in Water Under the Influence of Activators (The Molar Ratio Triazene: Activator = 1:1; Temperature 20°C).

Activator	Yield (mole %)		
	Ethane	Methanol	Aromatic amines
Without activators	0.0—2.7	95.0—100.0	97.8—100.0
Ascorbic acid	0.0	97.6	100.4
	0.1	92.3	100.6
	0.4	93.2	99.4
Hydroquinone	1.8	101.9	95.8
Ferrous sulfate	0.0	92.5	99.8
	0.0	94.8	99.9
Ferric sulfate	0.3	93.2	99.6

TABLE 6

Polymerization of Styrene Emulsion Under the Influence of Triazene (pH 6.8-6.9, Temperature 50°C, Time 5 Hrs)

Expt. No.	Triazene	Triazene added per 100 g styrene (in moles)	Decomp. of triazene (from nitrogen evolved) (in %)	Extent of polymerization (in %)
1	Without triazene	—	—	0.0
2	Methylphenyltriazene	0.001	12.5	4.2
3		0.0025	10.8	7.8
4		0.005	9.6	17.0
5		0.01	9.0	21.3
6*	Methylphenyltriazene	0.005	19.6	0.0
7	Butylphenyltriazene	0.0025	6.7	6.9
8		0.005	8.0	12.1
9		0.01	6.7	14.8

Some of the compounds which accelerate the decomposition of triazene in model emulsions were studied as activators for the polymerization process. The results from these experiments are given in Tables 7 and 8.

The accelerator actions of hydroquinone, ascorbic acid and glucose in the decomposition of the triazenes and in polymerization occur over comparatively wide pH ranges (from 4.5 to 10), while salts of iron, copper and aluminum are only effective at pH less than 7.

Discussion of Results

The experimental data obtained established the relation between the kinetics of decomposition in the triazenes and the kinetics of polymerization. All substances which accelerate the decomposition of the triazenes also accelerate the polymerization process. As follows from Tables 7 and 8, the decompositions of the triazenes due to the effect of hydroquinone are considerably more effective for the polymerization than are those occurring under the influence of the sulfates of iron, aluminum and copper.

TABLE 7

Polymerization of Styrene Emulsions Under the Influence of Methylphenyltriazene (0.005 g-mole per 100 g Styrene) in the Presence of Activators (Temperature 50°C, Time 5 Hrs)

Expt. No.	Activator	Molar ratio of triazene to activator	Optimum value of pH for polymerization	Decomp. of triazene to nitrogen (in %)	Extent of polymerization (in %)
1	Without activator	—	7.12	9.7	8.9
2	Sodium sulfite	0.5	5.8	39.0	40.7
3	Ferrous sulfate	0.1	5.2	51.4	66.4
4	Glucose	1.0	5.3	18.4	18.5
5	Hydroquinone	0.5	9.5	29.1	64.1
6	Ascorbic acid	0.5	4.4	65.7	77.7
7	Aluminum sulfate	0.1	4.2	87.0	30.0
8	Ferric sulfate	0.05	4.1	73.2	42.7
9	Cupric sulfate	0.05	5.8	72.6	37.6

* Polymerization in the presence of benzoquinone.

TABLE 8

Polymerization of Styrene Emulsion Under the Influence of Butylphenyltriazene (0.005 g-mole per 100 g Styrene) in the Presence of Activator (Temperature 50°C, Time 5 Hours)

Expt. No.	Activator	Molar ratio of triazene to activator	Optimum value of pH for polymerization	Decomposition of triazene to nitrogen (in %)	Extent of polymerization (in %)
1	Without activator	—	7.0	6.7	14.8
2	Sodium sulfite	0.5	5.8	21.5	43.4
3	Ferrous sulfate	0.1	5.3	29.0	55.0
4	Glucose	1.0	5.3	18.2	28.3
5	Hydroquinone	0.5	9.5	16.4	51.0
6	Ascorbic acid	0.5	4.4	not determined	81.0
7	Ferric sulfate	0.05	4.1	34.6	37.2

As was shown in the previous communication [3], the decompositions of the triazenes occur at very great rates, but are without effect as regards initiation of polymerization, when they occur in strongly acid media in the presence of mineral acids. Study of the composition of the product from the decomposition of methylphenyltriazene indicates that the course of the decomposition reactions of the triazenes is different, as methyl chloride is formed instead of methanol. The part due to this reaction increases as the pH of the medium falls. Of the two concurrent reactions:

$$C_6H_5NH{-}N{=}N{-}R \xrightarrow{+H_2O} C_6H_5NH_2 + RN{=}N{-}OH$$

$$C_6H_5NH{-}N{=}N{-}R \xrightarrow{+HCl} C_6H_5NH_2 + \underset{\displaystyle Cl}{\underset{|}{RN}}{\equiv}N,$$

only the first evidently leads to the initiation of the polymerization upon decomposition of the triazenes.

The most important result from the present work is the clarification of the role of activator in the decomposition processes of triazenes. Ascorbic acid, hydroquinone, ferrous and ferric salts of iron, and also sodium sulfite, undergo no chemical changes during the decomposition of the triazene, which enables us to conclude that their action is one of catalyzing the triazene hydrolysis.

Thus the mechanism by which the triazene systems act shows important differences from the oxidation-reduction systems, in which the polymerization initiating action is directly due to the interaction of the oxidizing and reducing agents. Stimulation of polymerization due to the action of alkyl-aromatic triazenes plus activators is due to the successive development of two processes: 1) combination of the triazene with water, under the influence of the activators (ionic catalysis) and 2) spontaneous decomposition of the resulting alkyl-diazohydroxides, giving free radicals.

SUMMARY

1) The activating action of a number of compounds in triazene decomposition processes and in polymerization has been established.

2) It has been shown that the activators undergo no chemical change in the triazene decomposition processes, and that they exert no influence on the composition of the products formed. From the results obtained the role of the activator in initiating polymerization is considered.

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SYNTHESIS AND TRANSFORMATION OF SOME DERIVATIVES OF DI-2-THIENYLMETHANE

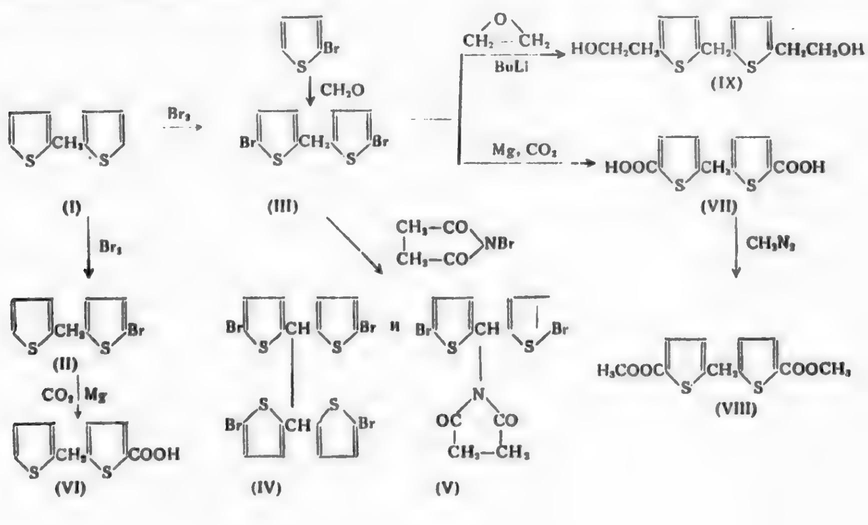
III. BROMINE-SUBSTITUTED DI-2-THIENYLMETHANES

Ya. L. Goldfarb and M. L. Kirmalova

In previous papers [1,2] we have described some mono- and di-functional derivatives of di-2-thienylmethane (DTM-I), which we obtained via their Li-compounds. It was shown to be quite probable that the synthesis of a similar series of compounds could be carried out by starting from the bromine derivatives of DTM. This caused us to study the bromination of DTM.

In choosing methods for the bromination of DTM it was expedient to use methods employed in making the bromothiophenes at first; e. g., by the action of bromine on a solution of the material in carbon tetrachloride [3]. But it was found even in the first experiments that under these conditions the reaction with DTM was accompanied by the marked formation of tars. On the other hand, bromination with a bromide/bromate mixture in a heterogeneous system gave mono- and di-bromo-dithienylmethane (II and III) in usable yields. In essence this method differs little from the old method in which the bromination of thiophene homologs was carried out with bromine water [4].

The dibromo derivative would most probably be expected to have the structure of (III), but since, by analogy with diphenylmethane, there are other possibilities for halogen substitution in DTM, we decided to check the correctness of this supposition by synthesis of a compound having the structure of (III) by an independent method. It was obtained by condensing 2-bromothiophene with formaldehyde in the presence of zinc chloride. The dibromo derivative obtained earlier did not differ in its properties from the dibromide made by condensation. Thus it was shown that in the bromination of DTM the bromine entered at the 2-position, forming di-5-bromothienyl-methane (III) and, if only one hydrogen atom was replaced, 5-bromo-di-2-thienyl-methane (II) was found.



The problem of synthesizing bromine derivatives of DTM is not eliminated by finding these data, since there remain unexplained conditions under which the bromine may displace hydrogen in the methylene group. In order to check up on this side of the process, it was convenient to use N-bromosuccinimide in the presence of benzoyl peroxide, since the hydrogen in the side chains of alkylthiophenes can be replaced with this reagent [5]. Nuclear substitution products are obtained at the same time, however. So, desiring to avoid the formation of a mixture of bromides, we decided to carry out the first experiments with DTM dibromide (III), rather than with DTM itself. The bromination was carried out using one equivalent of N-bromosuccinimide, while boiling in carbon tetrachloride; the process was accompanied by the formation of hydrogen bromide and bromine. Two crystalline substances were separated from the reaction product as judged by analysis; one compound was 1,1,2,2,-tetra-(5-bromo-2-thienyl)-ethane (IV) and the other N-di-(5-bromo-2-thienyl)-methyl-succinimide (V). The occurrence of these two compounds implies that the N-bromosuccinimide in fact attacks the methylene group in DTM. Since the mechanism by which N-bromosuccinimide acts is due to its homolytic fission into free radicals [6], $(C_4H_4O_2)N\cdot$, and bromine ion we may assume that this attack results in the free radical $(BrC_4H_2S)_2CH\cdot$ which dimerizes to the tetrabromide or interacts with the $(C_4H_4O_2)N\cdot$ radical giving (V). The occurrence of succinimide derivatives in the reaction with N-bromosuccinimide has been described earlier. For example, in the bromination of acridine N-(9-acridyl)-succinimide was formed, as well as the bromides [7].

When the bromination of unsubstituted DTM was carried out with an equivalent amount of N-bromosuccinimide in dry chloroform, in the cold and with benzoyl peroxide also present, we only succeeded in getting the mono-bromo derivative (II), with a small trace of the di-bromo-derivative (III). Di-2-thienyl-bromo-methane, which we tried to prepare as its salt with hexamethylenetetramine, was not found.

In order to test our hypothesis about the reactivity of the bromo-derivatives (II) and (III) we studied their reactions with magnesium and with lithium butyl. Unlike 2-bromothiophene, which forms organo-magnesium compounds readily, (II) and (III) did not react with magnesium, and only when ethyl bromide was present did the reaction go sufficiently rapidly. When the organo-magnesium compounds reacted with carbon dioxide, di-2-thienylmethane-5-carboxylic acid (VI) was formed, which we earlier made from lithium dithienylmethane [1], and di-(5 carboxy-2-thienyl)-methane (VII). The latter is mentioned in the paper by Buu-Hoi and Dat-Huong [8] (but no constants are given) as the starting material for making ω,ω-nonanedicarboxylic acid by hydrogenation with a dispersed nickel catalyst. In order to identify (VII) we made its dimethyl ester, (VIII). Using lithium butyl the bromine atoms in the di-bromo-dithienylmethane could be replaced by lithium. From the dilithium derivative and ethylene oxide di(5-β-hydroxyethyl-2-thienyl) methane, (IX), was formed, which we had made previously [1].

EXPERIMENTAL

Di-(5-bromo-2-thienyl)methane (III). A solution of 17.1 g of dithienylmethane (I) in 150 ml of benzene was mixed with 75 ml of concentrated hydrochloric acid, and 528 ml of 0.66 N bromide-bromate mixture was gradually added, with stirring, at (+2°). The stirring was continued for a further hour at room temperature; the benzene layer was then separated, washed with water, 10% alkali solution, again with water, and then dried over calcium chloride. The residue after removing the solvent in vacuo crystallized; a dark oil was extracted from it with alcohol. The dibromide, dried on a dish, weighed 23 g (72%). After recrystallizing from alcohol following treatment with activated charcoal, 18.5 g of the dibromide was obtained in the form of cream-colored plates, m.p. 59°C.

A further 3.2 g of dibromide was prepared from the mother liquor, of m.p. 59°C. The yield of recrystallized dibromide was 68%. After a second recrystallization from alcohol plus charcoal snow-white plates of m.p. 59–59.5° were obtained.

Found %: C 32.42, 32.27; H 1.73, 1.61. $C_9H_6Br_2S_2$. Calculated %: C 31.97; H 1.79.

The dibromide becomes brown rapidly in the light, but keeps well in darkness and in the cold. Dibromide which had been redistilled in vacuo went brown by the following day even on keeping in darkness at 0°C. The ether solution of the dibromide kept well at room temperature.

5-Bromo-dithienylmethane (II). A solution of 9 g of di-2-thienylmethane in 130 ml of benzene was mixed with 67 ml of concentrated hydrochloric acid, and 210 ml of 0.5 N bromide-bromate mixture were added with stirring over 2 hours to the above mixture at +2°. The mixture was stirred for a further hour at room temperature; the benzene layer was then separated, washed with water, dilute alkali, and water again, and dried with magnesium sulfate: the solvent was distilled off in vacuo (otherwise the bromide resinified), and the residue distilled. The following fractions were obtained:

1st, at 135–145° (6 mm), 1.1 g; 2nd, at 146–147° (6 mm), 8.2 g (64%) of monobromide; 3rd, at 160–180° (6 mm), 2.1 g of dibromide – crystallized in the receiver; yield 12.4%. The 2nd fraction was redistilled twice.

B. P. 128° (3 mm) n_D^{20} 1. 6339, d_4^{20} 1.550, MR 59.80; Calculated %: C 59.78.
Found %: C 41.64, 41.43; H 2.80, 2.66. $C_9H_7BrS_2$. Calculated %: C 41. 70; H. 2.72.

The bromide rapidly became brown on keeping.

Di-(5-bromo-2-thienyl)methane from 2-bromothiophene. A solution of 3 g of anhydrous zinc chloride in 3 ml of concentrated hydrochloric acid was mixed with 5 g of 2-bromothiophene, and then the mixture was cooled to −7° and 3 ml of a 37% solution of formaldehyde was added gradually, with stirring, after which the stirring was continued for a further 1.5 hours at room temperature. The reaction mixture was extracted with ether, the ether solution was washed with water, a bicarbonate solution, and water again, and then dried over magnesium sulfate. The residue after evaporating the ether crystallized on adding a trace of di-(5-bromo-2-thienyl)methane. The dibromide, when treated with charcoal and crystallized from alcohol melted at 59° (1.1 g). No depression of the m.p. was observed in a test mixture of the substance with di-(5-bromo-2-thienyl) methane obtained by bromination of DTM.

Di-2-thienylmethane-5 carboxylic acid (VI). 6.5 g of 5-bromo-di-2-thienylmethane (II), 1.25 g of magnesium (iodine activated), 2 ml of ethyl bromide, and 70 ml of absolute ether were mixed. The reaction began only on heating the mixture, and before long all the magnesium had dissolved. Boiling was continued for a further 30 minutes, and the cooled solution was then poured into a mixture of ether and dry ice. The precipitated material was treated with 10 ml of 25% sulfuric acid, the ether solution separated, washed with water and 3 times with a 3% solution of caustic soda. Dithienylmethane was precipitated from the alkaline solution with a 1:1 dilution of hydrochloric acid. Yield 4 g of acid of m.p. 103° (71%); after recrystallizing from water the m.p. was 105–106°. A test mixture with the acid prepared from lithium dithienylmethane [1] gave no depression of the m.p.

Di-(5 carboxy-2-thienyl)methane (VII). A mixture of 3 g of the bromo-derivative (III), 0.87 g of magnesium (iodine activated), 1.5 g of ethyl bromide, and 40 ml of absolute ether was heated to boiling, and a vigorous reaction lasting 10 minutes occurred; the magnesium was then almost completely dissolved, and an oily layer of the organo-magnesium compound, which is not soluble in ether, was formed at the end. The ether was poured off, and the organo-magnesium compound, dissolved in 10 ml of dry benzene, was gradually added to a mixture of ether and dry ice. The precipitated material was treated with 15 ml of 25% sulfuric acid. The ether solution was separated from the water one, and the acid extracted from it with a 3% solution of caustic soda. On acidifying the alkaline solution 2.1 g (84%) of the acid precipitated. The acid, when reprecipitated from methanol by water and recrystallized from acetic acid melted with decomposition at about 280° C.

Found %. C 48.72, 48.66; H 2.94, 3.15; S 24.16, 23.97. $C_{11}H_8O_4S_2$. Calculated %: C 49.23; H 3.01; S. 23.90.

Using diazomethane 0.4 g of the crude dimethyl ester of di-(5-carboxy-2-thienyl)methane (VIII) was obtained from 0.4 g of the acid: m. p. 74–74.5°

Found %: C 52.92, 52.96; H 4.19, 4.14; S 21.80, 21.97. $C_{13}H_{12}O_4S_2$. Calculated %: C 52.68; H 9.08; S 21.64.

Di-(5-β-hydroxyethyl-2-thienyl)methane. (IX). To a solution of 5.5 g of di-(5-bromo-2-thienyl)-methane in 25 ml of absolute ether at −10° was added 100 ml of a lithium butyl solution (26g/liter); the temperature rose to 0°. After stirring for 20 minutes at −2° a solution of 5 ml of ethylene oxide in 30 ml of ether was added, the temperature rising to + 13°. The deposit obtained was decomposed with alcohol and

acidified with water, the ether solution was washed with water, a bicarbonate solution, and again with water, and dried over magnesium sulfate. The residue after removing the ether crystallized. Dried on a porous plate it weighted 2.15 g; m. p. 50°C(from 50% alcohol). A test mixture with the glycol obtained from dilithium-dithienylmethane [1] gave no melting point depression. The urethane, m.p. 140–140.5° (from alcohol) was prepared from the glycol. A test mixture with the urethane made from the above glycol [1] gave no depression of the melting point.

On treating the ground material with ether and then distilling in vacuo 1.2 g of the crystalline glycol was obtained. The overall yield was 78%.

Bromination of di-(5-bromo-2-thienyl) methane (III) with N-bromosuccinimide. A mixture of 10 g of the di-bromo-derivative (III), 5.5 g of N-bromosuccinimide, 0.1 g of benzoyl peroxide, and 70 ml of dry carbon tetrachloride was boiled for 3 ½ hours. The solution became very dark, the reaction being accompanied by the evolution of bromine and hydrogen bromide. The precipitated succinimide was filtered off from the cooled solution, the filtrate was washed with water, a 10% soda solution, twice with water again, and dried over magnesium sulfate.

After removing the solvent a dark oil remained, which crystallized after washing it twice with hot alcohol. The substance obtained was again washed with a mixture made up of 4 volumes of alcohol to 1 of ether: 3.1 g of a yellow substance, A, was produced. On cooling the alcohol filtrate 2.2 g of a substance B was deposited, this being also washed with the alcohol–ether mixture. Both these substances were afterwards worked up separately, but it appeared that they were mixtures of the same substances.

Substance B was separated into two parts with cold acetone. The acetone-insoluble fraction (1.0g) melted at 140.5–141° after crystallizing from ethyl acetate and heptane.

Found %: C 31.61, 31.42; H 1.50, 1.42. M 690. $C_8H_{10}Br_4S_4$. Calculated %: C 32.06; H 1.49. M 674.19.

According to its composition and molecular weight this substance was 1,1,2,2-tetra(5'-bromo-2'-thienyl)-ethane (IV). The acetone-soluble fraction (1.2g) was N-di-(5-bromo-2-thienyl) methyl succinimide (V), melting at 108–110°, after 2-fold recrystallization from heptane its m.p. was 111–111.5°.

Found %: C 36.16, 36.05; H 2.19, 2.10; N 3.24, 3.49. $C_{13}H_{9}O_2NBr_2S_2$. Calculated %: C 35.88; H 2.08; N 3.22.

By treating substance A with acetone 1.9 g of the tetrabromide (IV) was obtained, together with 1 g of N-di-(5-bromo-2-thienyl) methyl succinimide. A further 0.9 g of this mixture precipitated from the alcohol mother liquor on prolonged standing.

After evaporating the alcohol mother liquor 4.9 g of unreacted dibromide (III) was obtained.

Bromination of DTM with N-bromosuccinimide. To a solution of 5 g of DTM and 0.35 g of benzoyl peroxide in 30 ml of dry chloroform cooled in ice was added a mixture of 5 g of N-bromosuccinimide with 0.35 g of benzoyl peroxide over 10 minutes. The dark solution so obtained was allowed to stand at room temperature for 1 ½ hours. Then it was filtered free of precipitated succinimide after cooling. The weight of the washed and dried succinimide was 2.3 g (85%). The filtrate was washed with a sodium bicarbonate solution, then with water, and dried over magnesium sulfate. To this solution was added 2.7 g of urotropine in chloroform. A small precipitate was formed on standing for two weeks, this containing no sulfur. The deposit was filtered off, the filtrate was washed with water to remove the urotropine, and dried over magnesium sulfate. The residue after removing the solvent was distilled in vacuo at 2 mm. The following fractions were obtained: 1st, at 110–125°, 1g which crystallized at once, this being unreacted DTM; 2nd, at 125–135°, n_D^{20} 1.6342–3.9 g of 5-bromo-di-2-thienylmethane (yield 68% of the reacted DTM); 3rd, at 155–160°, 1.1 g, which crystallized on cooling, m. p. 58 (from alcohol). A test mixture of this with di-(5-bromo-2-thienyl)-methane obtained by bromination with a bromide–bromate mixture gave no depression of the melting point.

In order to identify the 5-bromo-di-2-thienylmethane 1 g of the second fraction was brominated with a bromide–bromate mixture. The bromide produced had a m.p. of 59°C (from alcohol), and a test mixture with di-(5-bromothienyl) methane gave no depression of the melting point.

SUMMARY

1. The α-hydrogen atoms in the thiophene ring are replaced by bromine, giving mono-and di-bromo-derivatives on bromination of di-2-thienylmethane with a bromide-bromate mixture or with N-bromosuccinimide.

2. The structure of the di-bromoderivative is shown to be di-(5-bromo-2-thienyl)-methane, by synthesizing it from 2-bromothiophene.

3. These bromo derivatives react with lithium butyl, the halogen atoms being replaced by lithium: and with magnesium in the presence of ethyl bromide they form organo-magnesium compounds.

4. The action of N-bromosuccinimide in the presence of benzoyl peroxide on the dibromo derivatives is directed to the methylene group, as is shown by the formation of 1,1,2,2 tetra-(5'-bromo-2'-thienyl)ethane and N-di-(5-bromo-2-thienyl)-N-methyl succinimide.

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* T. P. = C. B. Translation pagination.

SOME ESTERS OF DIBUTYLARSINIC ACID

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The esters of dibutylarsinic acid have so far not been studied at all. No compounds of this type have been described in the literature. The present paper deals with the synthesis of several compounds of this class of organic arsenic compounds, and with the atomic refraction of the arsenic they contain.

The esters of di-n-butylarsinic acid were made by heating dibutyl arsenious oxide with the appropriate alcohols in the presence of anhydrous copper sulfate:

$$[(C_4H_9)_2As]_2O + 2ROH \longrightarrow 2(C_4H_9)_2AsOR + H_2O.$$

Di-n-butyl arsenious oxide is a colorless liquid, distilling at 164–167° (7 mm), and extremely readily oxidized in air. Four esters of di-n-butyl arsinic acid were synthesized, and their molecular refractions studied: the atomic refraction of the arsenic was then calculated. The physico-chemical constants of the esters are given in Table 1.

TABLE 1

No.	Ester	Boiling point	d_0^{20}	n_D^{20}	MR_D	$[AR_D]_{As}$	mean $[AR_D]_{As}$
1	Methyl	85–87° (12 mm)	1.0593	1.4653	57.49	10.98	11.16
2	Ethyl	89–91 (10 mm)	1.0318	1.4613	62.38	11.26	
3	Butyl	117–118 (10 mm)	1.0083	1.4627	71.59	11.23	
4	Octyl	167–169 (11 mm)	0.9780	1.4650	89.99	11.16	

All the esters oxidize rapidly in air, crystalline compounds being formed: but sulfur does not undergo addition when it interacts directly with them. If the esters drop on the skin they cause painful burns, blisters forming after 10-12 hours. The vapors irritate the respiratory tubes and the lungs when inhaled.

The atomic refraction of the arsenic in the esters of dibutylarsinic acid, (11.16), is extremely close to that of the arsenic in tertiary arsines, (11.55), as we have previously shown [1], and differs considerably from that of the arsenic in the phenylalkylarsinic acids, (11.78), which have been studied by Kamai and Starshov [2].

EXPERIMENTAL

Synthesis of the esters. In order to synthesize the esters of dibutylarsinic acid a three-necked flash was joined to an inverted condenser via a short adapter, the latter being charged with a roll of filter paper containing anhydrous copper sulfate: dibutyl arsenious oxide and a large excess (3-5 times) of the appropriate alcohol were placed in it. With the methyl and ethyl esters the copper sulfate was placed directly in the flask. The mixture was then heated to boiling for 2 hours, the excess alcohol being then distilled off, and the residue redistilled in vacuo. All the steps in the synthesis and in the distillation were carried out in an atmosphere of CO_2. The yields and analytical data for the esters of dibutylarsinic acid synthesized are given in Table 2.

TABLE 2

No.	Ester	Yield (in %)	% As	
			found	calculated
1	$(n\text{-}C_4H_9)_2AsOCH_3$	35.1	33.81	34.02
2	$(n\text{-}C_4H_9)_2AsOC_2H_5$	64.8	31.88	31.99
3	$(n\text{-}C_4H_9)_2AsOC_4H_9\text{-}n$	81.4	28.33	28.56
4	$(n\text{-}C_4H_9)_2AsOC_8H_{17}n$	72.3	23.40	23.53

Combination with sulfur. 7.7 g of the methyl ester of dibutylarsinic acid, 1.1 g of finely ground sulfur, and 25 ml of dry benzene were heated to boiling on a water bath for 4 hours in an atmosphere of CO_2. The sulphur was precipitated from the solution on cooling. After distilling off the benzene the unchanged methyl ester of dibutylarsinic acid was distilled away in vacuo.

SUMMARY

1. Four esters of dibutylarsinic acid have been obtained, and their molecular refractions studied, and the atomic refraction of the arsenic calculated.

2. The esters of dialkylarsinic acids may be obtained in good yield by reacting the dialkyl arsenious oxide with the alcohol.

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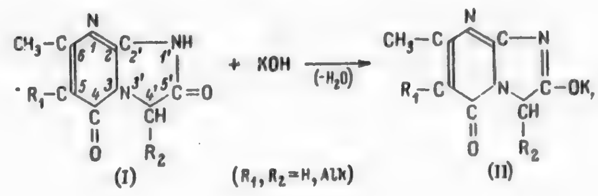
STUDIES IN THE PYRIMIDINOIMIDAZOLONE FIELD

III. PREPARATION OF PYRIMIDINOIMIDAZOLONE SALTS, AND ALKYLATION OF PYRIMIDINOIMIDAZOLONES

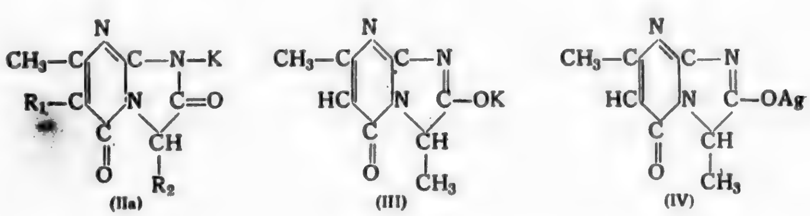
Yu. P. Shvachkin and M. A. Prokofyev

In previous articles [1, 2] it was stated that when 4-keto-pyrimidino-5-imidazolones (I) react with alkalis 1 mole of the substance combines quantitatively with 1 mole of the alkali. It appeared impossible to explain this effect by any sort of splitting of the bicyclic pyrimidinoimidazolone system, since metallic salts of the pyrimidinoimidazolones could be precipitated from the alkaline solutions. We should therefore conclude that the acid nature of the 4-keto-pyrimidino-5'-imidazolones is due to the special properties of the system, a definite group in the compound taking on so acid a character that it is capable of reacting quantitatively with alkali. It is most likely that the group responsible is the amide fragment of the five-member ring, the reaction with alkali then occurring as follows:



leading to the formation of salts of the type of (II).

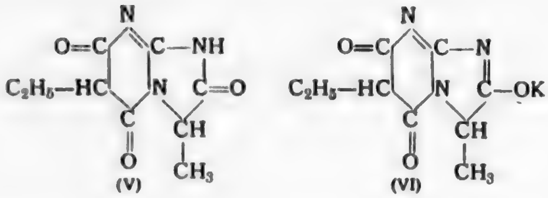
Another structure for the salts of pyrimidinoimidazolone theoretically possible is (IIa), a characteristic feature of this being the direct link between the metal and the nitrogen atom, which appears improbable.



The potassium salts of the 4-keto-pyrimidinoimidazolones (III and VIII) we prepared are high-melting colorless materials, which are hygroscopic. For example when (VIII) stands in air it forms a crystalline hydrate of composition $C_{10}H_{12}O_2N_3K \cdot 4H_2O$. Both salts dissolve readily in cold water, (VIII) also being soluble in ethanol.

The potassium salts of 4-keto-pyrimidinoimidazolones undergo double decomposition readily. For example, when (III) reacts with silver nitrate the corresponding silver salt (IV) is formed, this being practically insoluble in water. The potassium salts are strongly hydrolyzed in aqueous solution. Mineral acids, acetic acid and even carbonic acid decompose these salts, giving the respective free pyrimidinoimidazolones. Thus the 4-keto-pyrimidino-5'-imidazolones (I) are weaker than carbonic acid.

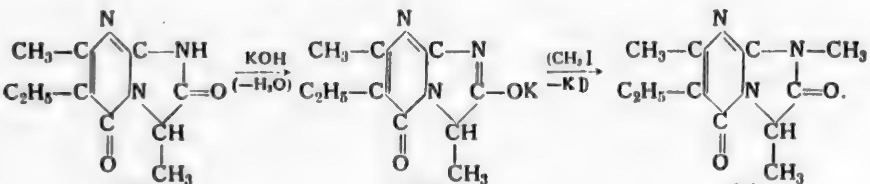
As distinct from these, the mono-potassium salt of the 4,6-diketo-pyrimidinoimidazolone (V), evidently of structure (VI), gives a neutral reaction in aqueous solution. Mineral acids



(V) (VI)

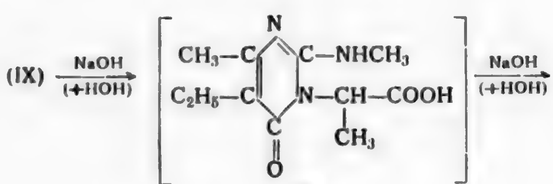
decompose it to give free pyrimidinoimidazolone (V). Glacial acetic acid decomposes the salt on standing, while carbonic acid has no effect. Thus the 4,6-diketo-pyrimidinoimidazolones (V) are stronger acids than carbonic, their acid properties exceeding those of 4-keto-pyrimidinoimidazolones (I) considerably.

We have studied the methylation of (VII) by methyl iodide in the presence of alkali. The reaction occurs via the formation of the potassium salt (VIII), and leads to the N-methyl derivative (IX), as follows: *

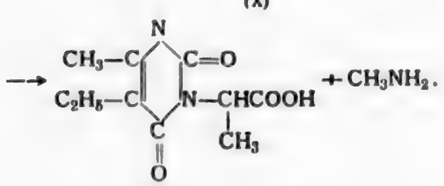


(VII) (VIII) (IX)

A proof that the methylation occurs at the nitrogen, and not at the oxygen, is given by the formation of methylamine, on alkaline hydrolysis of (IX), as well as the corresponding 2,4-keto-pyrimidine-(N_3)-alkylcarboxylic acid (XI). Hydrolysis proceeds, apparently by the intermediate formation of 4-keto-2-methyl-pyrimidine-(N_3)-alkylcarboxylic acid (X), according to the scheme:



(X)



(XI)

* That is with transfer of the active center [3]

We should state that the methyl derivative, (IX), differs markedly in its properties from the parent pyrimidinoimidazolone (VII). For example, the latter melts at 263°C, while (IX) melts at 160°C. The parent pyrimidinoimidazolone does not dissolve in the majority of organic solvents, but (IX) dissolves readily in aromatic hydrocarbons, chloroform, acetone and dichloroethane. As distinct from the pyrimidinoimidazolone (VII), its methyl derivative (IX), on heating with alkali, undergoes hydrolysis readily according to the above scheme, enabling one to pass from the pyrimidinoimidazolone structure to the pyrimidine-(N_3)-alkyl carboxylic acid. Finally, the parent pyrimidinoimidazolone, (VII) combines quantitatively with a mole of alkali [2], while its methyl derivative (IX), as would be expected, has no acid properties, being neutral. Thus the data given confirm the hypothesis above, that the acid properties of the 4-keto-pyrimidino-5'-imidazolones are due to the presence of a mobile oxygen atom in the amide fragment of the imidazole ring.

EXPERIMENTAL

1. Preparation of the salts of the 4-keto-6-methyl-dihydropyrimidino- (2,3:2',3')-4'-methyl-5'-tetrahydroimidazolone.

a) Potassium salt, (III). To an alcoholic solution of alkali, made up of 0.35 g of potassium hydroxide and 30 ml of anhydrous ethyl alcohol was added 1 g of the pyrimidinoimidazolone, gradually. The copious precipitate was filtered off, washed with dry alcohol and ether, and dried to a constant weight at 110°C in vacuo over phosphorus pentoxide. 0.96 g (73.5%) of a colorless lumpy material were obtained, which did not change on heating to 360°C, and which gave a positive test for potassium with sodium tetraphenylboron [4]. It was not soluble in alcohol or ether, but dissolved readily in cold water. The aqueous solution had a weakly alkaline reaction(pH 8).

Found %: C 44.55; H 3.80; N 19.36. $C_8O_8O_2N_3K$. Calculated %: C 44.22; H 3.71; N 19.34.

On acidifying the aqueous solution with dilute sulfuric acid a colorless material was precipitated. It was filtered off and recrystallized from water. Characteristic leaflets were obtained, melting with decomposition at 282°C, and giving no depression of the melting point when mixed with the parent pyrimidinoimidazolone. The parent pyrimidinoimidazolone was also precipitated on acidifying the potassium salt with acetic acid or on passing gaseous carbon dioxide into the aqueous solution.

b) Silver salt, (IV). To a solution of 0.43 g of the potassium salt of the pyrimidinoimidazolone in 2 ml of distilled water was added an aqueous solution of silver nitrate, made from 0.34 g of silver nitrate dissolved in 1 ml of distilled water. After two hours the precipitate of finely crystalline substance was filtered off, washed with cold water, and dried at 130°C. 0.53 g (93.2%) of a colorless substance was obtained, which was stable to light, and which decomposed on heating to 290°C. The compound did not dissolve in water or organic solvents.

Found %: N 14.70, 14.60. $C_8H_8O_2N_3Ag$. Calculated %: N 14.69.

2. Preparation of the potassium salt of 4-keto-6 methyl-5-ethyldihydropyrimidino-(2,3:2',3')-4'-methyl-5'-tetrahydroimidazolone (VIII). To an alcoholic solution of alkali, prepared from 0.28 g of potassium hydroxide and 20 ml of dry ethanol, was gradually added 1.03 g of the pyrimidinoimidazolone: the material then dissolved, and the mixture had a neutral reaction. The solution was evaporated to $^1/_4$ of the initial volume and placed in a refrigerator. The crystalline deposit was filtered off after 48 hours, washed with dry alcohol and ether, and dried at 130°C. 0.67 g (55.6%) of a colorless substance, melting with decomposition at 278°C was obtained, which gave a positive test for potassium with sodium tetraphenylboron [4]. For analysis it was dried at 110°C in vacuo over phosphorus pentoxide.

Found %: N 17.10, 16.91. $C_{10}H_{12}O_2N_3K$. Calculated %: N 17.13.

In order to determine the composition of the crystalline hydrate the material was left in air until weight increases were complete, and then dried to constant weight at 130°C.

Found %: H_2O 22.56. $C_{10}H_{12}O_2N_3K \cdot 4H_2O$. Calculated %: H_2O 22.71.

The compound did not dissolve in ether, but was soluble in dry etanol, and very readily soluble in cold water. The aqueous solution gave a weakly alkaline reaction (pH 8). On acidifying this solution with hydrochloric or acetic acid, as well as on passing gaseous carbon dioxide into the solution, a colorless material was observed to precipitate, which after recrystallizing from ethanol melted with decomposition at

The compound did not dissolve in ether, but was soluble in dry ethanol, and very readily soluble in cold water. The aqueous solution gave a weakly alkaline reaction (pH 8). On acidifying this solution with hydrochloric or acetic acid, as well as on passing gaseous carbon dioxide into the solution, a colorless material was observed to precipitate, which after recrystallizing from ethanol melted with decomposition at 263°, and gave no depression of the melting point with the parent pyrimidinoimidazolone.

3. Preparation of the potassium salt of 4,6-diketo-5-ethyl-tetrahydropyrimidino-(2,3;2' 3')-4'-methyl-5'-tetrahydroimidazolone, (VI). To an alcoholic solution of alkali, prepared from 0.28 g of potassium hydroxide and 30 ml of dry ethanol was gradually added 0.8 g of the pyrimidinoimidazolone. Precipitated material was filtered off after 2 hours, washed with dry ethanol, and dried in vacuo over phosphorus pentoxide, with heating to 110°. 0.74 g of (78.3%) of colorless finely crystalline substance was obtained, which melted with decomposition at 243° and gave a positive test for potassium with sodium tetraphenylboron [4].

Found %: N 17.01, 16.80 $C_9H_{10}O_3N_3K$. Calculated %: 16.99.

The compound did not dissolve in ether or dry ethanol, but dissolved readily in cold water. The water solution of this salt gave a neutral reaction. Acidification of the solution with either hydrochloric or acetic acid led to precipitation of a colorless substance, which, after recrystallizing from boiling water melted with decomposition at 290–291° and gave no depression of the melting point when mixed with the parent pyrimidinoimidazolone. Gaseous carbon dioxide did not decompose the salt when passed into its solution.

4. Methylation of 4-keto-6-methyl-5-ethyl-dihydropyrimidino(2,3:2',3')-4'-methyl-5'-tetrahydroimidazolone. To an alcoholic solution of alkali, made from 0.7 g of KOH and 30 ml of dry ethanol was added 2.1 g of the pyrimidinoimidazolone; to the solution so formed was added 5.7 g of methyl iodide, and the mixture was boiled under an inverted condenser on a water bath. The heating was stopped after 2 hours, and the mixture evaporated to dryness in vacuo, 5 ml of water was added to the residue, and the water suspension, which had strongly acid reaction, was treated with a 5% aqueous solution of potassium hydroxide. The insoluble material was filtered off and carefully washed with cold water, * and then recrystallized from 55 parts of boiling water and dried at 115°. 1.1 g (50%) of a colorless substance, which was coarsely crystalline, was obtained- this had a strong luster, and melted sharply at 160°. It crystallized from water in the form of flat rhombic plates.

Found %: C 59.77; H 6.89; N 18.99. $C_{11}H_{15}O_2N_3$. Calculated %: C 59.71; H 6.83; N 18.99.

The compound was readily soluble in dioxane, chloroform, dichloroethane and benzene: it dissolved on heating in acetone, methanol and ethanol, carbon tetrachloride, and in toluene; it was soluble in boiling water and in boiling xylene: it did not dissolve in ether, cold water or cold acetone.

5. Alkaline hydrolysis of 4-keto-6-methyl-5-ethyl-dihydropyrimidino-(2,3:2',3')-1',4'-dimethyl-5'-tetrahydroimidazolone. A solution of 0.5 g of the methylated pyrimidinoimidazolone in 25 ml of a 5% aqueous solution of sodium hydroxide was boiled for 25 hours. The methylamine evolved in the hydrolysis was absorbed in sulfuric acid in a Tishchenko bottle joined to an inverted condenser. At the end of the heating the hydrolyzate was acidified with concentrated hydrochloric acid to pH 1, the acid solution being then evaporated to 15 ml and cooled. The finely crystalline colorless liquid precipitated was filtered off, carefully washed with warm water, and dried at 130°. 0.3 g (57%) of α-[2,4-diketo-6-methyl-5-ethyl-tetrahydropyrimidine-(N_3)]-propionic acid were obtained; melting point 231–232°. The compound dissolved on heating in water, methanol, ethanol, and n-butanol, in acetone and dioxane, as well as in dilute alkalis: it dissolved with difficulty in chloroform, carbon tetrachloride, dichloroethane and cold water: it did not dissolve in benzene.

Found %: C 53.26; H 6.22; N 12.54. $C_{10}H_{14}O_4N_2$. Calculated %: C 53.09; H 6.24; N 12.38.

In order to assay the carboxyl a weighed amount of the substance was dissolved in a definite amount of 0.1 N. KOH, which was in excess of that calculated, the excess alkali being titrated with 0.1 N. H_2SO_4 and phenolphthalein.

Found %: 0.1 N. KOH: 2.45, 1.84. Calculated %: 0.1 N. KOH: 2.55, 1.96.

* This operation is of decisive importance since the methyl derivative cannot be recrystallized in the presence of potassium iodide.

The sulfuric acid absorbent was made alkaline, and the methylamine it contained was distilled off in steam into hydrochloric acid; after evaporating the hydrochloric acid solution 0.1 g of a crystalline colorless liquid melting at 226° and giving no depression of the melting point of a known specimen of methylamine hydrochloride. After treating the substance with picric acid, yellow plates, melting point 215°, were formed and on mixing a test specimen of this compound with a specimen of methylamine picrate there was no depression in the melting point.

SUMMARY

1. The metal salts of 4-keto and 4,6 diketo-pyrimidinoimidazolones were prepared (potassium and silver salts in the case of the 4-keto derivatives — the mono-potassium salts with the 4,6-diketo derivatives).

2. It has been shown that the potassium salts of 4-keto-pyrimidinoimidazolones are decomposed even by carbonic acid, whence it follows that the pyrimidinoimidazolones of this type are weaker acids than carbonic. On the other hand the mono-potassium salt of 4,6-diketopyrimidinoimidazolone is not decomposed by carbonic acid, which demonstrates the increased acidic properties of the 4,6-diketopyrimidinoimidazolones.

3. As for 4-keto-6-methyl-5-ethyl - dihydropyrimidino(2,3:2',3')-4'-methyl-5'-tetrahydroimidazolone it has been shown that in compounds of this type the mobile (acidic) hydrogen atom may readily be replaced on treating the compound with an alkyl halide (methyl iodide) in alcoholic alkali. It has also been shown that the methyl derivative formed is easily split up on heating with dilute alkali to the corresponding 2,4-diketo-pyrimidine-(N_3)alkylcarboxylic acid and methylamine, which shows that the alkylation occurs at the nitrogen.

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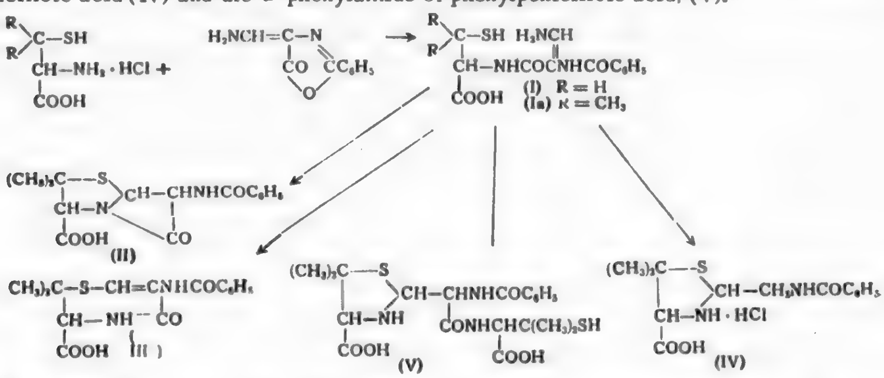
THIAZOLIDINE-4-CARBOXYLIC ACID AND ITS DERIVATIVES

VI. STUDY OF THE PRODUCTS FROM CONDENSING -AMINO-β-MERCAPTO ACIDS WITH 4-AMINOMETHYLENE-2-PHENYL-5-OXAZOLONE

I. T. Strukov

It has already been shown that 4-aminomethylene-2-phenyl-5-oxazolone is transformed to the methyl ester of β-imino-di-(α-benzoylaminoacrylic) acid in a methanol solution saturated with hydrogen chloride [1]. This enables us to assume that 4-aminomethylene-2-phenyl-5-oxazolone will react with cysteine and penicillamine hydrochlorides in an inert organic solvent in such a fashion as to first form N-(α-benzoylamino-β-aminoacryl) cysteine (I), or its penicillamine analog (Ia). The latter is of interest for transformation to the thiazolidine-β-lactam (II) of the 1-thia-3-benzoylamino-4-keto-5-aza-7,7 dimethyl-2-cycloheptene-6-carboxylic acid (III).

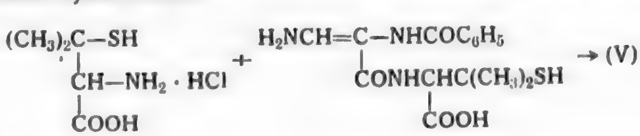
However, experiment shows that the main products from the reaction are the hydrochloride of the phenylpenicilloic acid (IV) and the α-phenylamide of phenylpenicilloic acid, (V).



When the dioxane in which the condensation was carried out was very wet, the main reaction product was (IV), the reaction occurring with the evolution of carbon dioxide.

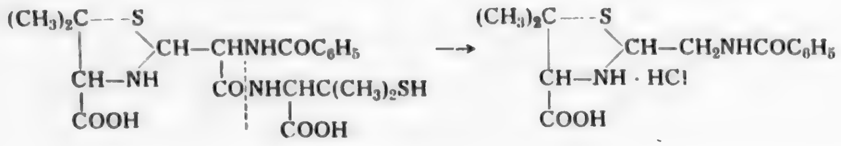
In order to establish the identity of the hydrochloride of phenylpenicilloic acid we prepared the diethylacetal of phenylpenicilloic acid [2]. Both compounds appeared identical as judged from the absence of a depression of the melting point in a mixture, the forms of the crystals and their solubilities in water.

The α-penicillamide of phenylpenaldic acid was formed on condensing 2 moles of penicillamine hydrochloride with 1 mole of 4-aminomethylene-2-phenyl-5-oxazolone. The reaction evidently proceeds via the intermediate N-(α'-benzoylamino-β-aminoacryl) penicillamine (Ia), which then reacts with a second molecule of penicillamine hydrochloride.



Compound (V), as the derivative of thiazolidine-4-carboxylic acid, dissolves in dilute sulfuric acid. This enables us to distinguish it from N-(formylhippuryl)-penicillamine, which was also produced in one of the experiments.

The structure of the α-penicillamide of phenylpenicilloic acid was demonstrated by decomposing it with hydrogen chloride in dioxane, when the hydrochloride of phenylpenicilloic acid was found:

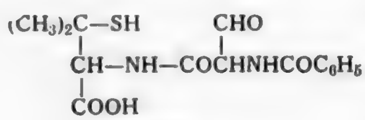


The reaction was accompanied by the evolution of carbon dioxide, as has already been noted in the monograph on penicillin [2] for the penicilloic acids, which readily decarboxylate on heating. When the time for which the penicillamine hydrochloride is heated with the 4-aminomethylene-2-phenyl-5-oxazolone is reduced, we also get a white crystalline material, in addition to (IV) and (V), the former being quite soluble in water, but insoluble in dilute mineral acids: it reduces the silver reagent well, and shows mercapto group reactions. By analysis and decomposition it corresponds to N-(formylhippuryl)-penicillamine (VI), since on heating with sulfuric acid in dioxane it is transformed to the hydrochloride of phenylpenicilloic acid. Evidently the splitting occurs at the amide link, the penaldic acid decarboxylates, and the benzoylaminoacetaldehyde reacts with the penicillamine hydrochloride.

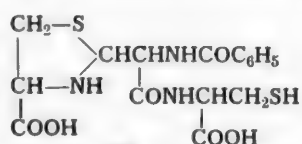
The acetals of analogous compounds have been described in a monograph [2] and in paper by Cornforth and Huang [3]. Bettenand [4] has also tried to obtain an analogous compound from the azide of benzylpenaldic acid and d,*l*-penicillamine.

Thus N-(formylhippuryl)-penicillamine is the first member of the N-(penaldyl)-penicillamines to be obtained in a crystalline state.

On condensing cysteine hydrochloride with 4-aminomethylene-2-phenyl-5-oxazolone, α-cysteineamide-desdimethyl-phenylpenicilloic acid (VII) was produced, which has properties resembling those of (V).



(VI)



(VII)

On decomposing (VII) with hydrogen chloride in dioxane the hydrochloride of 2-benzoylaminomethyl-thiazolidine-4-carboxylic acid was obtained, from which the acid of m.p. 176–177° (decomp.) was prepared, this being described in the monograph [2].

EXPERIMENTAL

Condensation of the hydrochloride of d,*l*-penicillamine with 4-aminomethylene-2-phenyl-5-oxazolone. 2 g of the hydrochloride of d,*l*-penicillamine, dried in vacuo at 80°C, 2 g of 4-aminomethylene-2-phenyl-5-oxazolone, and 20 ml of dry dioxane were heated to 90–95° for 8 hours in a flask with an inverted condenser, closed by a calcium chloride tube. On the next day the deposit was filtered off, washed with dioxane, and treated with 20 ml of hot water, and the undissolved yellow crystalline residue filtered off, washed with water, and dried. 0.15 g of a substance was obtained, this being identified by its not reacting with 4-aminomethylene-2-phenyl-5-oxazolone. After recrystallizing from methanol its m.p. was 215–216° (decomp.).

The mother liquor was evaporated to a volume of 5 ml and acidified with a few drops of hydrochloric acid. A white crystalline deposit, comprised of prism-like crystals, began to form at once: after filtering and washing this melted at 215–216° (decomp.).

Found %: C 50.85; H 5.90; N 8.54. $C_{14}H_{19}O_3N_2SCl$. Calculated %: C 50.82; H 5.79; N 8.46.

In order to identify this substance the hydrochloride of phenylpenicilloic acid was made from the diethylacetal of formylhippuric acid and penicillamine hydrochloride [2]. The mixture gave no depression of the m.p.

In order to study the solution the dioxane was distilled off in vacuo on a water bath and the residue treated with 25 ml of a 5% solution of ammonia. The insoluble light yellow residue, which appeared to be 4-aminomethylene-2-phenyl-5-oxazolone, was filtered off and dried. 0.63 g of material was obtained. In all 0.78 g of 4-aminomethylene-2-phenyl-5-oxazolone was recovered.

An almost white precipitate was produced from the filtrate on acidifying with hydrochloric acid until it was weakly acid to Congo red; this was filtered off, washed with water, and dried (weight 1.4 g). The precipitate was dissolved in 200 ml of ethyl acetate and washed with 5 lots of 20 ml of 18% hydrochloric acid. The acid solution was cautiously neutralized with dry sodium bicarbonate until it was weakly acid to Congo red, and extracted 3 times with ethyl acetate. The substance was again extracted from the ethyl acetate with a 5% solution of sodium bicarbonate, and after removing the residual ester in the solution it was precipitated by adding hydrochloric acid until the reaction was weakly acid (weight 0.8 g). In order to get the substance in a crystalline form it was dissolved in 500 ml of water, the solution being filtered from suspended mechanical impurities, and evaporated in vacuo on a water bath at a temperature not above 40°C (if the temperature is raised above this an oil is obtained instead of crystals). As the solution became concentrated the white crystalline substance came out as prismatic nodules. (m.p. 180–182° decomp.). Yield 0.55 g.

Found %: C 50.87; H 5.41; N 8.90; S 13.10. $C_{20}H_{27}O_6N_3S_2$. Calculated %: C 51.17; H 5.75; N 8.95; S 13.63.

The substance was readily soluble in 2 N hydrochloric acid, alcohol, acetone, ethyl acetate, slightly soluble in water, and insoluble in ether. It was oxidized by an iodine solution, gave the nitroprusside reaction for the mercapto group, and reduced the silver reagent slowly.

On heating 0.5 g of this in 10 ml of dry dioxane containing 0.1 g of hydrogen chloride at 60–70° for 20 hours a white crystalline deposit was formed (prisms). M.p. 215–216° (from water) (decomp.). A test mixture of this with the hydrochloride of the phenylpenicilloic acid gave no depression of m.p. On heating 0.5 g of the substance with 5 ml of 2N hydrochloric acid carbon dioxide was evolved (reaction with barium hydroxide).

On this basis the formula α-penicillamide of phenylpenicilloic acid was proposed for the compound of m.p. 180–182° (dec.).

In a second experiment which lasted 4 hours the α-penicillamide of phenlpenicilloic acid was prepared from the mass remaining after distilling off the dioxane, as well as N-(formylhippuryl)-penicillamine. On treatment with 2N hydrochloric acid this second compound (0.4 g) remained in the residue, and was purified by dissolving it in 500 ml of water and evaporating the solution in vacuo. Colorless prisms of m.p. 155–158° (dec.) were obtained. It reduces silver salts, is oxidized by a solution of iodine, and gives a coloration with $FeCl_3$.

Found %: C 52.67; H 5.66; N 8.24. $C_{15}H_{18}O_5N_2S$. Calculated %: C 53.25; H 5.32; N 8.27.

On heating 0.15 g of the substance in 3 ml of dioxane containing 2 drops of concentrated hydrochloric acid at 70° C for 24 hours, a precipitate (0.05 g) of the hydrochloride of phenylpenicilloic acid was produced. M.P. 214–215° (dec.) (from water). In another similar experiment it was shown that carbon dioxide is evolved on heating.

On this basis the formula N-(formylhippuryl)-penicillamine was proposed for the compound with the m.p. 155–158° (dec.).

Condensation of cysteine hydrochloride with 4-aminomethylene-2-phenyl-5-oxazolone. 2 g of cysteine hydrochloride, 2.4 g of 4-aminomethylene-2-phenyl-5-oxalone, and 15 ml of dry dioxane were heated at 90–95° for 5 hours in a small flask with a condenser closed by a calcium chloride tube. The dioxane was distilled off in vacuo, and the residue treated with 20 ml of a 5% solution of ammonia, and filtered off from the unreacted azalactone (1.27 g). The filtrate was acidified with hydrochloric acid, the precipitate filtered off and recrystallized from 20 ml of 50% ethanol, the solution being first purified with active charcoal. The material was again recrystallized from 50% ethanol. The light yellow very fine spherical crystals had m.p. 190–192° (dec.); they were almost insoluble in water, but quite soluble in alcohol and acetone. The substance was oxidized by a solution of iodine, gave a mercapto group reaction with sodium nitroprusside in alkaline solution, and reduced silver salts slowly.

Found %: C 46.34; H 4.84; N 9.89. $C_{16}H_{19}O_6N_3S_2$. Calculated %: C 46.47; H 4.60; N 10.13.

This compound is the α-cysteinamide of desdimethyl-phenylpenicilloic acid. 0.5 g of this substance was dissolved in 5 ml of dioxane containing 0.1 g of hydrogen chloride and was heated to 70°C. for 4 hours. The dioxane was distilled off in vacuo. The residual dark mass was treated with 5 ml of hot water, purified by boiling with charcoal, and neutralized to reaction weakly acid to Congo red. A deposit of 2-benzoylaminomethyl thiazolidine-4-carboxylic acid formed gradually (0.1 g). Thin needles, m.p. 176–177° (dec.). It was oxidized by a solution of iodine.

Found %: C 53.96; H 4.90; N 10.58. $C_{12}H_{14}O_3N_2S$. Calculated %: C 54.13; H 5.30; N 10.52.

The mother liquor, after removing the precipitate of 2-benzoylaminomethyl thiazolidine-4-carboxylic acid, gave an intense red coloration with sodium nitroprusside in an aqueous-ammoniacal medium (reaction for cysteine).

SUMMARY

1. On condensing 4-aminomethylene-2-phenyl-5-oxazolone with penicillamine hydrochloride we obtained the hydrochloride of phenylpenicilloic acid, the α-penicillamide of phenylpenicilloic acid, and N-(formylhippuryl)-penicillamine.

2. Cysteine hydrochloride gives the α-cysteinamide of desdimethyl-phenylpenicilloic acid with 4-aminomethylene-2-phenyl-5-oxazolone.

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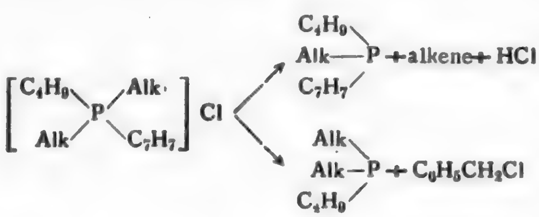
PREPARATION OF ASYMMETRIC PHOSPHONIUM COMPOUNDS WITH DIFFERENT ALIPHATIC RADICALS

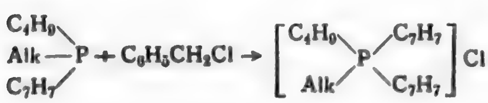
Gilm Kamai and L. A. Khismatullina

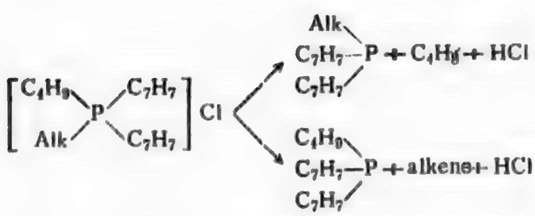
Many workers hace attempted to split up asymmetric phosphonium compounds of the type a b c d PHal into their optical antipodes during the last 50 years, so far without success [1]. Recently[2] we succeeded in preparing two diastereomeric ethylphenylbenzylallyl phosphonium salts of d-p-bromocamphor sulfonic acid in which the second asymmetric center was undoubtedly the phosphorus.

The present work has its main aim the synthesis of an asymmetric phosphonium compound containing different aliphatic radicals, and the attempt to resolve this into its optically active components. In order to synthesize the asymmetric phosphonium compounds we started with n-butyldichlorophosphine, which was transformed into dialkyl n-butyl phosphines via the action of the appropriate magnesium alkyl bromides. The colorless dialkyl n-butyl phosphines we prepared reacted with benzyl chloride, evolving heat and forming the dialkyl-n-butylbenzyl phosphonium chlorides in a crystalline form: these were very hygroscopic (as distinct from the dialkylphenylbenzyl phosphonium chlorides). Thermal decomposition of the above substituted phosphonium chlorides in an atmosphere of carbon dioxide gave the parent asymmetric phosphines.

The pyrolytic reaction probably occurs as below (by analogy with one such that one of us studied earlier [3]).







The following tertiary phosphines were made as the result of repeated fractional distillation: ethyl-n-butylbenzyl phosphine and n-propyl-n-butylbenzyl phosphine; these are mobile colorless liquids with sharp unpleasant odors, which mix readily with many organic solvents. We were only able to prepare ethyl-n-butylbenzyl allyl phosphonium bromide in a crystalline form by combining allyl bromide with these asymmetric phosphines and prolonged crystallization.

By reacting this phosphonium salt with the silver salt of d-p-bromocamphor sulphonic acid we prepared a syrupy substance, after removing the silver bromide from the aqueous solution; this substance would not crystallize even on prolonged keeping. But our failure to separate ethyl-n-butylbenzyl phosphonium bromide we are inclined to explain only as being due to the serious experimental difficulties both in the synthesis and in separating the asymmetric phosphonium compounds, and not (as some workers have done [4]) to the presence of an equilibrium dissociation of the phosphonium salts: a b c d P Hal   a b c P d Hal.

It is of interest to note that it is comparatively rarely possible to obtain salts of these optically active anions with these compounds in a crystalline state when the residues in the optically active acids are halogen-substituted. Of the asymmetric phosphonium salts reported in the literature during the past 15 years only three form crystals when the anions of the optically active acids are halogen-substituted.

EXPERIMENTAL

The starting material— n-butyldichlorophosphine—was made by the action of phosphorus trichloride on di-n-butyl cadmium [5]. B.p. 62–64° (23 mm), n_D^{20} 1.4850.

Preparation of diethyl-n-butylphosphine. To an ether solution of magnesium ethyl bromide, made from 24 g of magnesium and 116 g of ethyl bromide, was cautiously added an ether solution of 23 g of n-butyldichlorophosphine, in a current of an inert gas, with ice cooling. Later the reaction mixture was heated on a water bath for 1 hour. After cooling it was treated with a solution of ammonium chloride. The ether layer was removed and dried with magnesium sulfate, after which the ether was distilled off, the residual liquid being distilled over in vacuo in a current of carbon dioxide. The yield was 72%.

B. P. 110–111° (100 mm), d_4^{20} 0.8094, n_D^{20} 1.4596, MR_D 49.36; Calculated 49.38.
Found %: P 21.09. $C_8H_{19}P$. Calculated %: P 21.23.

Diethylbutyl phosphine is a colorless liquid with a sharp unpleasant odor, which dissolves in alcohol, ether and other organic solvents.

The other phosphines were made in a fashion analogous to that above, their properties being given in Table 1.

TABLE 1

No.	Formula	Boiling point	d_4^{20}	n_D^{20}	MR_D		Yield (in %)
					calc.	found	
1	$(CH_3)_2C_4H_9P$	69–70° (100 mm)	0.4855	1.4458	40.15	40.03	44.4
2	$(C_2H_5)_2C_4H_9P$	72 (100 mm)	0.8094	1.4596	49.38	49.36	42.0
3	$(C_3H_7)_2C_4H_9P$	107–108 (33 mm)	0.8130	1.4579	58.62	58.38	42.5

Preparation of diethyl-n-butylbenzyl phosphonium chloride. To 34 g of diethyl-n-butyl phosphine was added dropwise 30 g of benzyl chloride in a current of carbon dioxide. The reaction was rapid, a large amount of heat being evolved. After two recrystallizations from alcohol/acetone mixtures a crystalline substance of m.p. 148–149°.

Found %: P 11.65; Cl 11.62. $C_{15}H_{26}ClP$. Calculated %: P 11.37; Cl 11.61.

Diethyl-n-butylbenzyl phosphonium chloride is quite soluble in alcohol, water, hot acetone and benzene, but does not dissolve in dry ether.

The syntheses of the other phosphonium chlorides (which are colorless crystals) were analogous. Some data on these are given in Table 2.

TABLE 2

No.	Formula	Melting point	% P		% Cl	
			calc	found	calc	found
1	$(CH_3)_2(n\text{-}C_4H_9)(C_7H_7)PCl$	147—148°	12.68	13.10	—	—
2	$(C_2H_5)_2(n\text{-}C_4H_9)(C_7H_7)PCl$	148—149	11.37	11.76	11.61	11.62
3	$n\text{-}C_3H_7)_2(n\text{-}C_4H_9)(C_7H_7)PCl$	154.5—155	10.32	10.53	—	—

Pyrolysis of diethyl-n-butylbenzyl phosphonium chloride. Experiment 1. 23.7 g of diethyl-n-butylbenzyl phosphonium chloride and 1.5 g of diethyl-n-butyl phosphine were heated in a Klaisen flask on a metal bath at atmospheric pressure in a current of carbon dioxide. The decomposition began at bath temperatures above 300°C, ethylene and butylene being evolved. 20.9 g of a yellow liquid was obtained. This liquid was washed with a strong solution of caustic soda to remove hydrogen chloride, and the ether extract was further dried with sodium sulfate. After distilling off the ether the substance obtained was distilled in vacuo. The following fractions were obtained: 1st, up to 70°(52 mm) 7 g; 2nd, 89–139° (52 mm) 1.4 g, n_D^{20} 1.4965; 3rd, 103–118° (2 mm), n_D^{20} 1.5317, 4.8 g; 4th, 160–165° (2 mm), n_D^{20} 1.5713, 3.1 g.

Experiment 2. This was carried out in a similar fashion to 1. 21.4 g of diethyl-n-butylbenzyl phosphonium chloride were taken for decomposition, together with 1 g of the 1st fraction from the previous experiment. 1700 ml of gas and 17.5 g of a yellow liquid were obtained. After working up this liquid and vacuum-distilling it the following fractions were obtained: 1st, up to 120° (100 mm) n_D^{20} 1.4740, 33 g; 2nd, 103–153° (52 mm), n_D^{20} 1.4955, 0.7g; 3rd, 112–140° (5 mm), n_D^{20} 1.5337, 5.4 g; 4th, 163–178° (5 mm), n_D^{20} 1.5678, 1.7g. After a repeat distillation of the 2nd fractions from the two experiments diethyl n-butyl phosphine was obtained. Dibenzyl-n-butyl phosphine was separated from the 4th fractions. By further distillation of the united 3rd fractions (from experiments 1 and 2), a substance of b.p.125–129° (6 mm) was obtained.

Found %: P 15.15 15.30. $C_{13}H_{21}P$. Calculated %: P 14.90.

Ethyl-n-butylbenzyl is a mobile colorless liquid.

d_4^{20} 0.9338, n_D^{20} 1.5310, MR_D 68.92. $C_{13}H_{21}P$. Calculated 68.87.

Preparation of ethyl-n-butylbenzylallyl phosphonium bromide. To a solution of 4.3 g of ethyl-n-butylbenzyl phosphine in 30 ml of absolute ether was added 2.5 g of allyl bromide in 20 ml of ether. The reaction mixture was observed to become hot upon addition. After part of the solvent had evaporated a syrupy mass remained, which crystallized after some hours. The crystals formed were washed with ether and dried in a desiccator. Yield 4.6 g. M.p. 87–89°.

Found %: P 10.4. $C_{16}H_{26}BrP$. Calculated %: P 10.6.

Ethyl-n-butylbenzylallyl phosphonium bromide forms hygroscopic crystals, quite soluble in alcohol, water and hot acetone, but poorly so in benzene: it is not soluble in ether.

The experiments on resolving the ethyl-n-butylbenzyl phosphonium bromide with the silver salt of d-p-bromocamphor sulfonic acid were not successful. Syrupy non-crystallizable materials were obtained in these experiments.

Preparation of propyl-n-butylbenzyl phosphine. Propyl-n-butylbenzyl phosphine was obtained, as in the previous analogous cases, by pyrolysis of di-n-propyl-n-butyl-benzyl phosphonium chloride. Propyl-n-butylbenzyl phosphine is a colorless liquid.

B. P. 118–120° (1 mm) n_D^{20} 1.5090, d_4^{20} 0.9467.
Found %: P 13.90. $C_{14}H_{23}P$. Calculated %: P 13.95.

An attempt to prepare propyl-n-butylbenzylallyl phosphonium bromide. 2.2 g of propyl-n-butylbenzyl phosphine and 1.3 g of allyl bromide were heated in a current of carbon dioxide for 3 hours. The product was purified from the parent unreacted material by treatment with ether. The reaction product, like the other phosphonium salts, is insoluble in ether. It was a syrupy mass which did not solidify even on prolonged storage in a desiccator.

SUMMARY

1. Some new phosphines and phosphonium salts have been prepared and studied.

2. Ethyl-n-butylbenzylallyl phosphonium bromide has been synthesized for the first time – this being a phosphonium compound with different alkyl radicals. An attempt to resolve it into its optically active components was not successful.

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DERIVATIVES OF BICYCLO (2,2,1) HEPTANE

1. CONDENSATION OF 2-ACYL-3-CHLOROBICYCLO (2,2,1) HEPTANES WITH MALONIC ESTER AND RELATED COMPOUNDS

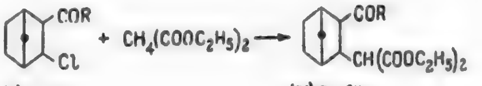
N. K. Kochetkov and A. Ya. Khorlin

The condensation of β-chlorovinylketones with diene hydrocarbons which had already been performed in our laboratory [1,2], makes the 2-acyl-3-chlorobicyclo(2,2,1)hept-5-enes easily accessible, as well as their saturated analogs, which may serve as convenient starting materials for the synthesis of different alicyclic systems. Derivatives of this type are the cyclic β-halodiketones, which must have active halogen atoms and carbonyl groups favorable to the closing of a fresh alicyclic ring. The activity of chlorine in compounds of this type in exchange with other nucleophilic groups was shown by one of us in collaboration with Karpeisky [3] in the case of replacement of the chlorine in 2-acyl-3-chlorobicyclo(2,2,1) hept-5-enes by alkoxy- and acyloxy-groups: the replacement of the halogen by a phenoxy-group had been earlier demonstrated [4]. In order to evaluate the convenience of using the chlorodiketones, made by the diene synthesis with β-chlorovinylketones, for building up polycyclic systems, it was necessary to determine whether this replacement of the chlorine atom could be carried out in chloroketones in order to form a fresh carbon-carbon bond. The clarification of this possibility forms the subject of the present paper.

With this end in view we studied the condensation of the 2-acyl-3-chlorobicyclo(2,2,1)hept-5-enes, and their saturated analogs, the 2-acyl-3-chlorobicyclo(2,2,1)hept-5-anes, with compounds with active methylene groups, of which malonic ester was taken first of all, as well as ethylmalonic and acetoacetic esters.

The 2-acyl-3-chlorobicyclo(2,2,1)hept-5-enes required were prepared by a general method [1]; one of the compounds prepared is described here for the first time (the 2-propionyl derivative). The corresponding saturated chloroketones were made by catalytic hydrogenation of the unsaturated adducts over a palladium catalyst [1]; the 2-propionyl-3-chlorobicyclo(2,2,1)heptane and 2-butyryl-3-chlorobicyclo(2,2,1)heptanes (II) and (III) are also described for the first time.

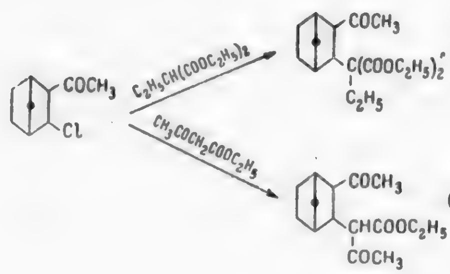
We studied in detail the reaction which is of interest to us here: the condensation of 2-acyl-3-chlorobicyclo(2,2,1)hept-5-ene (I) with malonic ester. It would appear that it may be carried out in accordance with the usual method of malonic ester synthesis in alcohol or benzene, almost equal yields (60–69°) being obtained in both varients, although the separation of the condensation product was somewhat simpler in working with the alcohol solutions. In order to obtain optimum yields it was necessary to use excess of malonic ester, and the equivalent amount of sodium. The reaction went just as smoothly with homologs of (I), i.e. with the 2-propionyl- and 2-butyryl-3-chlorobicyclo(2,2,1)heptenes, (II) and (III) respectively. The yields of condensation products were the same in both alcohol and benzene, being 63-67%.



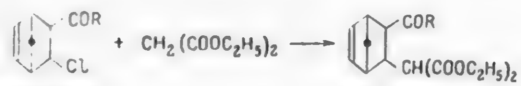
(I) R = CH_3, (II) R = C_2H_5, (III) R = C_3H_7, (IV) R = CH_3, (V) R = C_2H_5, (VI) R = C_3H_7.

The 2-acyl-bicyclo(2,2,1)heptyl-3-malonic esters so obtained, (IV)–(VI), the structures of which were confirmed by all the subsequent work described in this paper, were high-boiling oily substances, which were completely stable on keeping. They were identified via their carbonyl-group derivatives (dinitrophenylhydrazones, oximes).

Other compounds with active hydrogen atoms also react in an analogous manner under the same conditions — e.g. ethyl malonic ester and acetoacetic ester, giving the corresponding condensation products (VII) and (VIII) with yields of 40–70%. Thus the reaction described is of a fairly general type.



The condensations of unsaturated chloroketones — i.e. the direct products from the diene synthesis of cyclopentadiene with the β-chlorovinylketones, (IX), (X). This reaction is of interest from points of view other than the purely synthetic one. It is now well known that the replacement of the halogen atom in compounds close in type to the 2-acyl-3-chlorobicyclo(2,2,1)hept-5-enes, such as, for instance, in 2-chloro- or 2-bromobicyclo(2,2,1)hept-5-enes, is accompanied by a rearrangement of the carbon skeleton, giving rise to derivatives of tricyclene [5]. It was of interest to elucidate the character of the reaction when there was a carbonyl group β to the halogen in the 3-chlorobicyclo(2,2,1)heptane ring. The research showed that the unsaturated chloroketones, (IX), (X), react with malonic ester just as smoothly as do their saturated analogs, and give normal condensation products in good yield. This extends the field open to the reaction we have developed considerably:



(IX) $R = CH_3$, (X) $R = C_6H_5$, (XI) $R = CH_3$, (XII) $R = C_6H_5$

The condensation product which contains a benzoyl group, (XII) could not be successfully purified by distillation (at 0.1 mm), or obtained in a crystalline form, and it was transformed to the corresponding dibasic acid without purification, the latter being prepared in an analytically pure form.

The structures of the compounds obtained, which are esters of unsaturated ketoacids, (XI) and (XII), were demonstrated by hydrogenating one of them, (XI), over palladium, this giving the saturated compound (IV), this being identical with the substance obtained by condensing the saturated chloroketone with malonic ester. The fact that they were the same was shown from the identity of the ultraviolet absorption spectra of both compounds (see Figure), as well as from the agreement between the constants from a direct comparision of their solid derivatives in test mixtures. *

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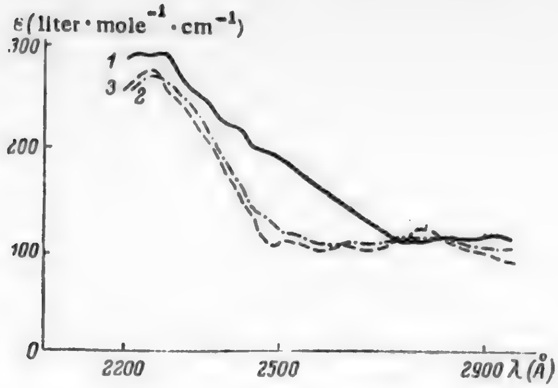
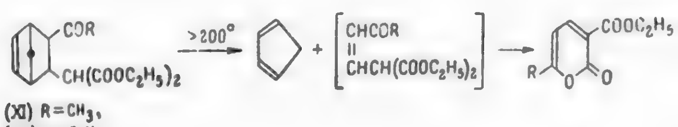
* The spectra of these specimens were taken in alcoholic solution on an EMR-2 monochromater fitted with a photoelectric recorder in the Spectroscopy Laboratory of the Lomonosov State University, Moscow, by V. M. Gryaznov and V. D. Yagodsky, to whom the authors are deeply indebted.



Absorption Spectra.
1) 2-acetylbicyclo(2,2,1)heptene-5-yl-(3)-malonic ester (XI)
2) 2-acetylbicyclo(2,2,1) heptyl-(3)-malonic ester, derived from (XI);
3) the same, obtained by condensation

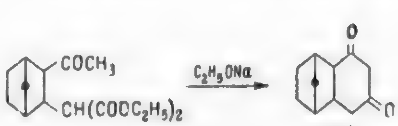
Thus we may consider that it has been fully demonstrated that the replacement of the chlorine atom in unsaturated chloroketones such as (IX), (X), a fresh carbon-carbon bond being formed, occurs without a rearrangement of the carbon skeleton. This again confirms the hypotheses made by one of us and Karpeisky [3] as to the regularities in halogen replacement in the 2-acyl-3-chloro(2,2,1)hept-5-ene system. One of the possible explanations is that the reaction operates via the preliminary elimination of hydrogen chloride, the α, β-unsaturated ketone formed then reacting in a Michael type reaction.

The fact that the bicyclo-(2,2,1)hept-5-ene skeleton remains intact in (XI) and (XIII), and the correctness of their proposed structures, is also confirmed by the interesting retrodiene decomposition reaction which begins on heating these substances above 200°C. The substance decomposes, eliminating cyclopentadiene which was identified via its adduct with malonic anhydride, the liberation of the corresponding β-acylvinyl malonic ester in this process undergoing further cyclization under the conditions of the pyrolysis to give the 6-alkyl(aryl)-3-carbethoxy-α-pyrone (cf[6]), which was also separated from the decomposition products:



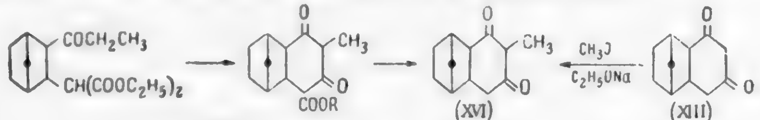
(XI) $R = CH_3$,
(XII) $R = C_6H_5$.

The latter section of the present work was devoted to the study of the cyclization of the products obtained by condensing chloroketones with malonic ester, (IV – VI), with the aim of forming a new alicyclic ring. On heating the saturated ketoester (IV) with an alcohol solution of sodium ethoxide, distilling off the alcohol at the same time, an intramolecular acylation of the methyl group by the acetyl residue occurs, and a new ring is closed. At the same time the second carbethoxy group is split off, this giving 1,3-diketo-5,8-endomethylenedecalin (XIII):



(XIII)

The substance obtained gave no color with a solution of ferric chloride, this being typical of the β-diketones in the decalin series [7], but it showed the other properties typical of β-diketones. We verified this by methylation, via the action of methyl iodide on (XIII) in the presence of sodium ethoxide, this giving 2-methyl-1,3-diketo-5,8-endomethylenedecalin, (XVI). As we had in mind to elucidate the possibilities of cyclizing the other ketoesters, (IV) - (VI), we had obtained, we carried this out with the following homolog - the ketoester (V). A substance of m.p. 116-119° was thereby obtained, which seemed to be a derivative of diketodecalin which still contained a carboxyl group, being a mixture of 2-methyl-1,3-diketo-4-carbethoxy-5,8-endomethylenedecalin (XIV), and the corresponding acid, (XV). It is clear that in this case, as distinct from the reaction with (IV), the cyclization is not accompanied by decarboxylation. But by simply heating the (XIV) - (XV) mixture with aqueous alkali we obtained 2-methyl-1,3-diketo-5,8-endomethylenedecalin, (XVI), which was identical with the substance obtained by methylating (XIII).



(XIV) $R=C_2H_5$; (XV) $R=H$ (XVI) (XIII)

Thus this work established a two-step process for building up a new ring in the bicycloheptane system by condensing a chloroketone with malonic ester, followed by cyclization. In this connection we must note that only cyclic derivatives were obtained at once on repeating the same reaction with malonic ester with derivatives of acetylcyclohexene [7,8]. We were successful in finding conditions in which the reaction could be stopped at the initial stage of the cyclization, which is of decided interest in extending the possibilities for synthesis. It was also found in our instances that the corresponding cyclization products could be separated as secondary products (e.g. in the condensation of (I) with malonic ester). It would appear that the deciding factor which determines the final result is the temperature. On raising the temperature above 60° C the reaction can be made to give the cyclic product to a considerable extent. E.g., on condensing the chloroketone (II) with malonic ester at 60–65° a yield of 35–40% of a substance with a m.p. of 116–118° was obtained, in addition to the substituted malonic ester (V); this substance appeared also to be a mixture of (XIV) and (XV). Thus the condensation of the bicyclic ketones (I)-(III) may be controlled to give the substituted malonic esters (IV)-(VI) or their cyclization products, (XIII)-(XVI), by varying the reaction conditions.

EXPERIMENTAL

1) 2-Propionyl-3-chlorobicyclo(2,2,1)hept-5-ene. This was made by the general method developed earlier [1], from 78.0 g of the ethyl-β-chlorovinylketone and 100.0 g of cyclopentadiene. Yield 110-115 g (91-96 %). After repeated distillation the substance had the following constants:

B. P. 91-94% (1 mm), n_D^{20} 1.4985, d_4^{20} 1.1322, MR_D 47.88; Calculated % 48.41.
Found %: Cl 19.36, 19.26. $C_{10}H_{13}OCl$. Calculated %: Cl 19.20.

It is a colorless oily liquid with a characteristic smell of camphor, which gradually goes brown upon prolonged keeping, hydrogen chloride being evolved.

2) 2-Propionyl-3-chlorobicyclo(2,2,1)heptane (II). This was made by hydrogenation of 20 g of 2-propionyl-3-chlorobicyclo(2,2,1)hept-5-ene over 0.3 g of 6% palladium on barium sulfate in 50 ml of ether, as described earlier [1]. Yield 18 g (90%).

B. p. 90-92° (5 mm), n_D^{20} 1.4890, d_4^{20} 1.1137, MR_D 48.35; calculated 48.86.
Found %: Cl 18.51, 18.41. $C_{10}H_{15}OCl$. Calculated %: OCl 18.99.

It is a colorless oily liquid with a characteristic smell of camphor which darkens on prolonged storage.

3) 2-Butyryl-3-chlorobicyclo (2,2,1) heptane (III). This was made in an analogous fashion, by hydrogenation of 2-butyryl-3-chlorobicyclo (2,2,1) hept-5-ene. Yield 92%.
B. P. 108-110° (5 mm), n_D^{20} 1.4860, d_4^{20} 1.0781, MR_D 53.45; Calculated %: 53.48.
Found %: Cl 17.33, 17.20. $C_{11}H_{17}OCl$. Calculated %: 17.66.

4) 2-Acetylbicyclo(2,2,1)-heptyl-(3)-malonic ester (IV). Method A - To a suspension of sodio-malonic ester, made in the usual way from 65 g of malonic ester and 8.5 g of sodium in 400 ml of dry benzene, was gradually added, with cooling and vigorous stirring, 25 g of 2-acetyl-3-chlorobicyclo(2,2,1)heptane, the temperature of the reaction mixture being kept at about 0°C. When all the chloroketone had been added the temperature was gradually raised to boiling, slow boiling being continued for 12 hours. On cooling 300 ml of water

was added, the benzene layer was separated and washed twice with a 10% aqueous solution of caustic soda: on acidifying the aqueous alkali extract about 0.5 g of an oily substance separated, this giving a color with ferric chloride, and being evidently a product from further cyclization of (IV); it was not studied more closely. The benzene layer was dried over magnesium sulfate, the solvent was distilled off, and the residue distilled in vacuo, the fraction of b.p. 145-150° (1 mm) being taken. Yield 25.0 g (57.5%). After redistillation 24.3 g was obtained of a substance of b.p. 137.5-139.5° (0.5 mm), n_D^{20} 1.4710, which crystallized completely on cooling to colorless rhombic prisms of m.p. 19–21°.

Found %: C 64.70, 64.79, H 7.94, 8.07. $C_{16}H_{24}O_5$. gives C 64.84%, H 8.17%.

Method B. To an alcohol solution of sodio malonic ester, made in the usual way from 33.0 g of malonic ester and 4 g of sodium, in 150 ml of dry alcohol was gradually added 17.3 g of 2-acetyl-3-chlorobicyclo-(2,2,1)heptane in 50 ml of dry alcohol, the temperature of the reaction mixture being kept at about that of the room. The mixture was then heated for 20 hours at 45-50°C, and after cooling was poured into 1 liter of water: the oil which separated was taken up in ether, and the extract dried over magnesium sulfate. After distilling off the solvent and distilling the residue in vacuo, 19.0 g (64.2%) of a substance with b.p. 150-154° (1.5 mm) n_D^{20} 1.4714 was obtained.

Found %: C 64.68, 64.69%, H 8.16, 8.09% $C_{16}H_{24}O_5$ gives C 64.84%, H 8.17%.

2-Acetylbicyclo-(2,2,1)-heptyl-(3)-malonic ester dissolves well in the usual organic solvents, but poorly in petroleum ether, gives no color with an alcohol solution of ferric chloride, and does not decolorize water and acetone solutions of potassium permanganate.

The oxime was made by heating it for 6 hours with an alcoholic solution of hydroxylamine hydrochloride. After recrystallization from aqueous alcohol it gave colorless needles, m. p. 87-88°.

Found %: C 61.87%, H 8.07% $C_{16}H_{25}O_5N$ gives C 61.71%, H 8.07%.

The 2,4-dinitrophenylhydrazone was made by the usual method. It forms orange crystals, m.p. 124-125° (from aqueous alcohol)

Found %: N 11.58, 11.65. $C_{22}H_{28}O_8N_4$ gives N 11.84%.

5) 2-Propionyl-bicyclo(2,2,1)-heptyl-(3)-malonic ester (V). Made via method B, from 18.6 g of 2-propionyl-3-chlorobicyclo(2,2,1)heptane, 33 g of malonic ester and 5 g of Na in 150 ml alcohol at 40-45° C. Yield 22.1 g, 63.5%.

B. p. 148-150° (3 mm), n_D^{20} 1.4710
Found %: C 65.73 65.83% H 8.26, 8.44% $C_{17}H_{26}O_5$ gives C 65.78%, H 8.44%.

It is a colorless viscous non-crystallizing oil, giving no color with alcoholic ferric chloride, and does not decolorize permanganate solutions.

The 2,4,-dinitrophenylhydrazone forms orange crystals, m.p. 118-119.5° (from alcohol, dried at 60°C and 4 mm).

Found %: N 11.77, 11.82. $C_{23}H_{30}O_8N_4$ gives N 11.94%.

6) 2-Butyrylbicyclo-(2,2,1)-heptyl-(3)-malonic ester (VI). This was made, by analogy with method B, from 9.4 g of 2-butyryl-3-chlorobicyclo(2,2,1)heptane, 10.0 g of malonic ester and 1.4 g of sodium in 50 ml of alcohol. Yield 11.5 g (67.5%).

B. P. 154-156° (2 mm), n_D^{20}. 1.4698.
Found %: C 66.33, 66.52%, H 8.59, 8.43%. $C_{18}H_{28}O_5$ gives C 66.64%, H 8.70%.

It is a colorless viscous non-crystallizing oil, giving no color with alcoholic ferric chloride, and does not decolorize permanganate solutions.

The 2,4-dinitrophenylhydrazone was precipitated as a dark non-crystallizable oil.

7) Ethyl-2-acetyl-bicyclo(2,2,1)-heptyl-(3)-malonic ester (VII). This was made, by analogy with method A, from 25.0 g of 2-acetyl-3-chlorobicyclo(2,2,1)heptane, 35.0 g of ethyl malonic ester and 3.45 g of sodium in 250 ml of dry benzene. Yield 20.0 g (42%).

B. P. 151-154° (1 mm). n_D^{20} 1.4770.

Found %: C 66.54 66.64% H 8.62, 8.70% $C_{18}H_{28}O_5$ gives C 66.64%, H 8.70%.

Obtained by analogy with method B from 17.5 g of 2-acetyl-3-chlorobicyclo(2,2,1)heptane, 50 g of ethyl malonic ester and 4.6 g of sodium in 200 ml of alcohol. Yield 13.5 g. (41.5%)

B. p. 146-147° (0.5mm), n_D^{20} 1.4740.

Found %: C 66.59, 66.73% H 8.86, 8.70% $C_{18}H_{28}O_5$ gives C 66.64%, H 8.70%.

It is a colorless viscous non-crystallizing oil, giving no color with alcoholic ferric chloride, and does not decolorize permanganate solutions.

The 2,4-dinitrophenylhydrazone forms orange crystals, m.p. 103-104° (from aqueous alcohol).

Found %: N 11.22, 11.01% $C_{24}H_{29}O_8N_4$ gives N 11.15%.

8) 2-Acetylbicyclo(2,2,1)heptyl-(3)acetoacetic ester (VIII). To sodio-acetoacetic ester (35 g acetoacetic ester and 4.6 g of sodium in 150 ml of dry alcohol) was gradually added 17.5 g of 2-acetyl-3-chlorobicyclo-(2,2,1)heptane in 50 ml of alcohol, the mixture temperature being kept close to that of the room. Then the mixture was heated for 17 hours to 45-50°C, and on cooling was worked up as in method B. Distillation gave 19.5 g (73.3%) of the substance.

B. p. 144-146° (1.5 mm), n_D^{20} 1.4803.

Found %: C 68.07, 68.04%, H 8.43, 8.44% $C_{15}H_{22}O_4$ gives C 68.15% H 8.33%.

It is a colorless viscous non-crystallizing oil, giving no color with alcoholic ferric chloride, and does not decolorize permanganate solutions.

9) 2-Acetylbicyclo(2,2,1)heptane-5-yl-(3)-malonic ester (XI). This was made, by analogy with method B, from 17.5 g of 2-acetyl-3-chlorobicyclo(2,2,1)hept-5-ene, 33.0 g of malonic ester and 4.6 g of sodium, in 200 ml of alcohol. Yield 23.5 g (78%); b.p. 148.5-149.5° (0.3 mm). On cooling, the substance deposited as a crystalline mass of m.p. 19-20°.

Found %: C 65.04, 65.15% H 7.44, 7.51% $C_{16}H_{22}O_5$ gives C 65.29%, H 7.53%.

It is a colorless oil, becoming yellow on storage, and instantly decolorizes potassium permanganate in acetone, gives no color with alcoholic ferric chloride.

The 2,4-dinitrophenylhydrazone forms orange crystals of m.p. 126-127° (from aqueous alcohol).

Found %: N 11.79, 11.91% $C_{22}H_{23}O_8N_4$ gives N 11.88%.

Hydrogenation of the ketoester (IX). 6.66 g (XI) was hydrogenated over 1.0 g of palladium on barium sulfate (6% palladium) in 15 ml of alcohol. 570 ml of hydrogen was absorbed in 35 minutes (15°, 747 mm), which corresponds to 0.270 mole, and the hydrogenation ceased. After the usual working-up and distillation 6.5 gm of 2-acetylbicyclo(2,2,1)heptyl-(3)-malonic ester, b.p. 146-147° (1 mm), n_D^{20} 1.4710, m.p. 19-20°.

The oxime, m.p. 85-86°, in a test mixture with a specimen of that described in section 1) gave no depression of the m.p.

The 2,4-dinitrophenylhydrazone, m.p. 124-125°, in a test mixture with a specimen of that described in section 1) gave no depression of the m.p.

10) 2-Benzoylbicyclo(2,2,1)heptene-5-yl-(3)-malonic acid (corresponding to the ester XII). The reaction between 25.0 g of malonic ester, 2.3 g of sodium and 12.6 g of 2-benzoyl-3-chlorobicyclo(2,2,1)hept-5-ene in 120 ml of benzene was carried out as in method B (heating for 20 hours at 50-60°). After distilling off the solvent and excess malonic ester in vacuo (at 190-200° and 0.3 mm) there remained a sticky brown mass, which did not crystallize on prolonged cooling and storage. The yield of impure substance was 13.1 g.

To a solution of 15.0 g of caustic potash in 10 ml of water was added a solution of 8.0 g of impure (XII) in 30 ml of methanol, with stirring. The mixture was heated for 1 hour on a water bath, was cooled, the precipitate was filtered off, washed with absolute ether and dried in vacuo. The colorless crystalline

potassium salt obtained was that of 2-benzoyl-bicyclo(2,2,1)heptene-5-yl-(3) malonic acid (8.2 g): it was dissolved in water, and the solution cautiously acidified with dilute hydrochloric acid; the oil which precipitated was taken up in ether and the ether extract dried over sodium sulfate. After distilling off the solvent there remained crystals which, after drying in vacuo, had a m.p. of 135-137° (dec.). Yield 6.2 g.

Found %: C 67.55, 67.56, H 5.60, 5.63%. $C_{17}H_{16}O_5$ gives C 67.99%, H 5.37%.

The colorless crystals dissolved readily in alcohol, ether and benzene, but were insoluble in water and petroleum ether.

11) Pyrolysis of 2-acetylbicyclo(2,2,1)heptene-5-yl-(3)-malonic ester (XI). 20 g of (XI) was heated to 240-260° in a Klaisen flask with fractionating column and descending condenser. About 7 ml of distillate came over, consisting of alcohol and cyclopentadiene; this was treated with maleic anhydride; the precipitated adduct was filtered off, and after recrystallization from petroleum ether it gave colorless crystals of m.p. 163-164°. A test mixture with a genuine specimen of the adduct gave no depression of the m.p. The residue in the distillation flask was distilled off in vacuo, the fraction of b.p. 130-180° (20 mm) being taken; this crystallized almost completely in the receiver. The crystals were drained on a porous plate, and after recrystallizing from ligroin 8.1 g of yellowish crystals was obtained, m.p. 87-88°. A test mixture with a genuine specimen of 6-methyl-3-carbethoxy- α-pyrone gave no depression of the melting point.

Found %: C 59.45, 59.39%, H 5.57, 5.54%. $C_9H_{10}O_4$ gives: C 59.34%, H 5.53%.

Literature data for 6-methyl-3-carbethoxy- α-pyrone [9] m.p. 87°C.

12) Pyrolysis of 2-benzoylbicyclo(2,2,1)heptene-5-yl-(3)-malonic ester (XII). The material, which was obtained by a method analygous to that described in method B from 15.0 g of 2-benzoyl-3-chloro-bicyclo-(2,2,1)hept-5-ene, 26 g of malonicester and 2 g of sodium in 120 ml of dry benzene was distilled in vacuo 180-220° (15 mm) after distilling off the excess malonic ester, the low-boiling fraction being collected in a trap cooled by an acetone-solid carbon dioxide mixture. The distillate collected in the trap was treated with maleic anhydride. After recrystallizing from petroleum ether colorless crystals of the adduct were obtained, m.p. 162-164°; a test mixture with a known specimen of the adduct of cyclopentadiene with maleic anhydride gave no depression of the melting point. The main fraction, which was collected in a receiver, crystallized completely; after recrystallizing from a benzene petroleum ether mixture 5.9 g (38 %, calculated back to the chloroketone) of 6-phenyl-3-carbethoxy- α-pyrone was obtained as green-yellow needles of m.p. 105.5-106.5°.

Found %: C 68,90, 68.84%, H 5.15, 5.11%. $C_{14}H_{12}O_4$ gives : C 68.83%, H 4.95%.

Literature data for 6-phenyl-3-carbethoxy- α-pyrone [6]: m.p. 105-106°.

13) 1,3-Diketo-5,8-endomethylenedecalin(XIII). 10.0 g of 2-acetylbicyclo(2,2,1)heptyl-(3)-malonic ester and an alcohol solution of sodium ethoxide (from 1.5 g of sodium and 30 ml of alcohol) were placed in a distillation flask, and the alcohol was slowly distilled off, beginning at atmospheric pressure, and then at 10-15 mm on an oil bath, heated to 110-130° until the residue in the flask no longer flowed freely. On cooling it was dissolved in 100 ml of water, the neutral substances were extracted with ether, and the water layer was cautiously acidified with dilute hydrochloric acid. The oil evolved was taken up in ether, the ether extract was washed a few times with a 10% soda solution, and the soda solution acidified with dilute hydrochloric acid. The oil liberated gradually crystallized, and the crystals were filtered off and dried in vacuo over phosphorus pentoxide. The substance gave a weak color with an alcoholic solution of ferric chloride (weight 5.95 g, m.p. 144-148°). After recrystallizing from acetone, 2.88 g of the pure substance (XIII) was obtained, m.p. 159.5 – 160° . After partial evaporation of the mother liquor, a further 1.0 g of less pure (XIII), of m. p. 155-158° was obtained. In the residue from the recrystallization there was a small amount of non-crystallizing oil, which gave a brown color with ferric chloride solution (this was evidently 1,3-diketo-4-carbethoxy-5,8-endomethylenedecalin). The overall yield of (XIII) was 3.88 g (64.7%).

Found %: C 74.39, 74.53%, H 7.89, 8.14 %. $C_{11}H_{14}O_2$ gives: C 74.13%, H 7.92%.

It formed colorless lamellae, which dissolved readily in alcohol, chloroform, but poorly in benzene; they are insoluble in petroleum ether. It gives no color with an alcohol solution of ferric chloride.

14) 2-Methyl-1,3-diketo-5,8-endomethylenedecalin, (XVI). On treating 10.0 g of 2-propionyl-bicyclo-(2,2,1)heptyl-(3)-malonic ester with a solution of sodium ethoxide (from 1.5 g of sodium) in alcohol, in a manner similar to the above, we obtained 5.1 g of a crystalline substance of m.p. 116-120°, evidently a mixture of (XIV) and (XV). The substance gave a brown color with a ferric chloride solution and decolored a potassium permanganate solution. 4.8 g of this substance was heated for 8 hours with 50 ml of a 2 N solution of caustic soda at 65-70°. The solution was filtered after cooling, and the filtrate was cautiously acidified with dilute hydrochloric acid; the crystals deposited were filtered off, dried in vacuo, and recrystallized from ethyl acetate. Yield of (XVI) 3.2 g (52.3%), m.p. 147-148.5°.

Found %: C 75.02, 75.19%, H. 8.41, 8.31%, $C_{12}H_{16}O_2$ gives: C 74.97; H 8.39%.

The colorless crystals dissolve readily in alcohol, ether, acetone and acetic acid; they give no color with ferric chloride.

15) Preparation of (XVI) by direct condensation of 2-propionyl-3-chlorobicyclo(2,2,1)heptane with malonic ester. The interaction of 37.2 g of (II), 66.0 g of malonic ester and 10.0 g of sodium in 150 ml of alcohol was performed as described in section 5). The reaction mixture was heated for 20 hours at 60°. After the usual working-up with ether, 2-propionyl-bicyclo(2,2,1)heptyl-(3)-malonic ester (V), was extracted. Yield 56%, b.p. 147-150° (3 mm), n_D^{20} 1.4712. The aqueous solution, after removing (V), was acidified with hydrochloric acid, the oil liberated was extracted with ether and the extract treated with a 10% soda solution. After acidifying the soda solution with dilute hydrochloric acid a crystalline substance was precipitated, which had a m.p. of 116-118° (15.2 g) after recrystallizing from cyclohexane, and from its properties and a test mixture it was identical with the substance described in the previous section. 15.0 g of the substance was treated, as above, with 150 ml of a 2 N solution of caustic soda. Yield of (XVI) 12.9 g (33.5%), computed on the basis of (II), m.p. 148-149°. A test mixture with a specimen of (XVI) from section 14) gave no depression of the melting point.

16) Methylation of 1,3-diketo-5,8-endomethylenedecalin. To an alcoholic solution of sodium ethoxide (from 0.23 g of sodium in 20 ml of alcohol) was added a solution of 2.5 g of the diketone (XIII) in 15 ml of dry alcohol and 1 ml of methyl iodide. The mixture was heated to boiling for 6 hours until neutral to phenolphthalein, after which it was poured into 100 ml of water, the oil liberated being taken up in ether and the extract washed with a 10% soda solution. On acidifying the soda solution an oil was liberated, which crystallized completely after 1-2 hours. The crystals were drained on a porous plate and, after recrystallizing from aqueous acetone, 0.53 g of 2-methyl-1,3-diketo-5,8-endomethylenedecalin (XVI) was obtained, m.p. 147.5-148.5°. A test mixture with specimens of (XVI) from previous experiments gave no depression of the melting point.

SUMMARY

1) On condensing 2-acyl-3-chlorobicyclo(2,2,1)heptanes with malonic ester, ethyl malonic ester and acetoacetic ester, the corresponding 2-acylbicyclo(2,2,1)heptyl-(3) derivatives of malonic and acetoacetic esters are obtained in good yields.

2) It has been shown that the condensation of 2-acyl-3-chlorobicyclo(2,2,1)hept-5-enes with compounds having active methylene groups (malonic ester) is not accompanied by rearrangement of the bicycloheptene skeleton; in this way the 2-acylbicyclo(2,2,1)heptene-5-yl-(3)-derivatives of the malonic esters are obtained.

3) It has been shown that the 2-acylbicyclo(2,2,1)heptene-5-yl-(3)malonic esters undergo retrodiene decomposition on heating, eliminating cyclopentadiene and 6-substituted 3-carbethoxy-α-pyrone, these being derived from thermal cyclization of the β-acylvinyl malonic ester.

4) Cyclization of the 2-acylbicyclo(2,2,1)heptanes to the corresponding 1,3-diketo-5,8-endomethylenedecalins has been carried out.

5) It has been shown that under more elastic conditions the condensations of 2-acyl-3-chlorobicyclo-(2,2,1)heptanes with malonic ester are accompanied by partial cyclization to the 1,3-diketo-5,8-endomethylenedecalins.

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THE INTERACTION OF COPPER TETRAPHENYL BORON WITH CARBONYL COMPOUNDS

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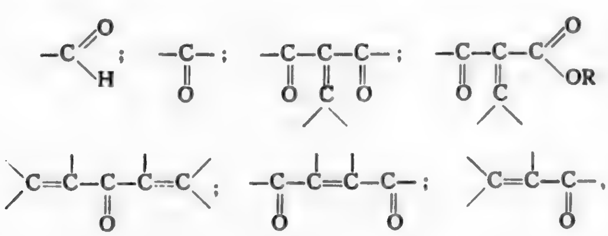
The addition of metallo-organic compounds, particularly organo-magnesium compounds, to carbonyl compounds has been widely studied. When RMgX or RLi reacts with aldehydes or ketones, which occurs heterolytically, alkoxides are formed, and in the case of α,β-unsaturated ketones, where both 1,2-and 1,4-addition can occur with the Grignard reagent, enolates are also found.

The addition of organo-metallic compounds to esters of unsaturated acids has been studied comparatively little. Grignard [1] described the reaction between methyl magnesium iodide and α-ethylidineacetoacetic ester, which gives isopropyl acetoacetic ester (if equivalent amounts of the reagents are used), which was identified as the semi-carbazone of isobutyl methyl ketone, obtained after hydrolysis: the isopropylacetoacetic ester was not separated in a pure form. In the presence of excess α-ethylideneacetoacetic ester polymers of indefinite composition were observed to form.

Addition in the 1,2-position is more characteristic of organo-lithium compounds [2]. E. g. lithium phenyl gives diphenylstyryl-carbinol (89%) with benzalacetophenone; when ω-styryl lithium acts on dibenzalacetone the product of 1,2-addition is also obtained: tri-(ω-styryl)-carbinol. Benzalacetomesitylene combines with lithium phenyl at the 1,4 position, due to steric hindrance, β,β diphenylpropiomesitylene being formed.

The characteristic properties of organo-lithium compounds are completely lost in the $LiB(C_6H_5)_4$, complex which Wittig [3] obtained by addition of lithium phenyl to boron triphenyl. Lithium phenyl, being in a complex compound, does not react with carbonyl compounds.

The present paper is concerned with the reactions of a complex organo-metallic compound of low stability (copper tetraphenyl boron) with carbonyl compounds. The copper tetraphenyl boron studied was prepared by a method earlier proposed by Nesmeyanov, Sazonova et al [4], in which potassium tetraphenyl boron is heated with copper acetoacetic ester in solution in pyridine. Substances of several types are used as carbonyl compounds:

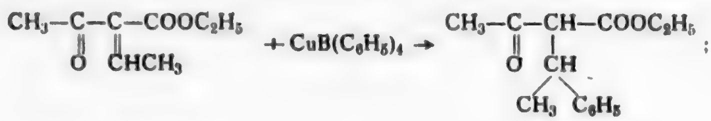


i. e. benzaldehyde, benzophenone, dibenzalacetone, benzalacetophenone, benzalacetomesitylene, benzalacetylacetone, α-benzalacetoacetic ester, α-ethylideneacetoacetic ester, benzalbenzoylacetic ester and α, β-dibenzoylethylene.

The reactions were carried out in toluene. The pyridine complex of copper tetraphenyl boron dissolves inthe toluene, subsequently decomposing. To the toluene solution of the carbonyl compound at 75-80° the pyridine complex of copper tetraphenyl boron was added gradually, with stirring. When the reaction was over the toluene solution was treated with dilute acetic acid; the toluene was then distilled off in vacuo, and the reaction product purified by recrystallizing from a suitable solvent.

Under such conditions the following compounds react readily, giving good yields:

1) α-Ethylidene acetoacetic ester, giving α-phenethylacetoacetic ester:

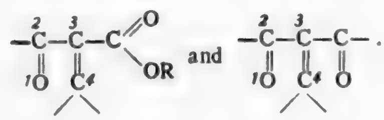


2) Benzalbenzoylacetic ester, giving benzhydrylbenzoylacetic ester;
3) α-Benzalacetoacetic ester, giving α-benzhydrylbenzoylacetic ester;
4) Benzal-acetylacetone, giving benzhydryl-acetylacetone.

The rest of the compounds quoted above do not react under the conditions described. Benzalacetophenone, which does not react with copper tetraphenyl boron at 75-80°, adds on phenyl, giving β-β-diphenylpropiophenone on heating to boiling on a water bath. Phenyl does not combine with dibenzalacetone either at 75-80°, on a boiling water bath, nor again in a melt on heating to 160°C.

Finally, benzaldehyde, benzophenone, dibenzoylethylene and benzalacetomesitylene do not add on phenyl either on heating in a solvent, or on fusing at a higher temperature. When copper tetraphenyl boron reacts with benzaldehyde diphenyl is eliminated, and the unchanged benzaldehyde is recovered.

Thus this work shows that phenyl combines readily and in good yield with the following systems:



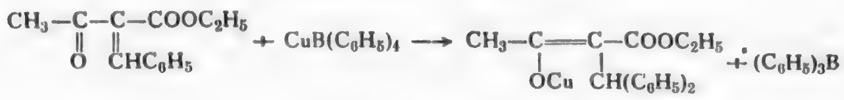
So, unlike organo-magnesium compounds which combine with α, β unsaturated compounds in both the 1,2- and 1,4- positions, with copper tetraphenyl boron the phenyl only combines in the 4-position; in general, 1,2-addition is not observed.

Parent material	Substance obtained	Yield (in %)
α-Ethylidene acetoacetic ester	α-Phenethylacetoacetic ester	> 100
Benzalbenzoylacetic ester	Benzhydryl-benzoylacetic ester	98
α-Benzalacetoacetic ester	α-Benzhydrylacetoacetic ester	70
Benzalacetylacetone	α-Benzhydryl-α-acetylacetone	61
Dibenzalacetone	α-Benzhydryl-2'-benzalacetone	42
Benzalacetophenone	β,β-Diphenypropiophenone	29
α,β-Dibenzoylethylene	—	—
Benzalacetomesitylene	—	—
Benzaldehyde	—	—
Benzophenone	—	—

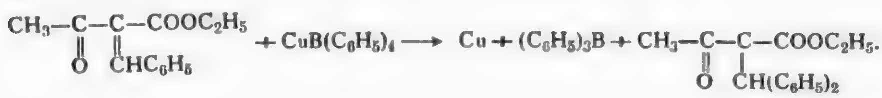
As is clear from the table, the yield of the adduct of phenyl and α-ethylideneacetoacetic ester is greater than 100%, if we assume that only one phenyl group comes from $CuB(C_6H_5)_4$. This means that the copper tetraphenyl boron can give more than one phenyl residue, which differs from the data of Razuvaev and Brilkina [5], who have shown that when potassium tetraphenyl boron reacts with mercury only one of the four phenyl groups present in the anion complex takes part in the formation of the organo-mercury compound.

As regards the mechanism by which the pyridine complex of copper tetraphenyl boron reacts with carbonyl compounds, we may presume that

1) the reaction goes via the formation of the copper enolate:



or 2) the addition of the phenyl is of radical type:



The radical formed abstracts hydrogen from the solvent (toluene) or from the CH_3 group of the benzalacetoacetic ester, giving benzhydrylacetoacetic ester. A number of reactions is known where free radicals react with the solvent.

In order to elucidate the reaction mechanism some attempts were made to isolate the copper enolate. For this purpose the reaction between copper tetraphenyl boron and benzalacetoacetic ester was carried out in a nitrogen atmosphere, under the conditions described above, but with this difference, that the toluene solution was not treated with acetic acid and water, in order to avoid hydrolysis of the enolate. Reactions carried out in this fashion led to the separation of copper metal and to benzhydrylacetoacetic ester. The copper enolate (Cu^+ or Cu^{++}) was not obtained.

Further, the decomposition of the pyridine complex of copper tetraphenyl boron was carried out in another solvent — carbon tetrachloride. It was found that in this solvent the copper tetraphenyl boron gave no benzhydrylacetoacetic ester with benzalacetoacetic ester, but that the copper tetraphenyl boron reacted more rapidly with the carbon tetrachloride; the pyridine salt of triphenyl boron was than separated, together with benzoic acid (after hydrolysis of the benzotrichloride). The reaction may be represented as follows:

$$CuB(C_6H_5)_4 + CCl_4 \longrightarrow C_6H_5CCl_3 + CuCl + (C_6H_5)_3B.$$

The course of the reaction is evidently very much more complex (since not much benzoic acid was found) and it requires additional study in order to elucidate the other reactions occurring at the same time as the above.

Thus all the experimental data obtained from the study of the reactions of copper tetraphenyl boron with carbonyl compounds, namely the formation of diphenyl (in the reactions with benzaldehyde), addition of phenyl radicals in the 4-position only, the separation of copper metal and the formation of benzhydrylacetoacetic ester on hydrolysis, indicate a radical mechanism for the reaction, unlike the usual organo-metallic compounds RMgX and RLi which react heterolytically with carbonyl compounds; undergoing addition at the 1,2- and 1,4- positions.

EXPERIMENTAL

I. Reactions of copper tetraphenyl boron with carbonyl compounds.

1) With α-benzalacetoacetic ester. a). To 2.25 g of benzalacetoacetic ester in 20-25 ml of toluene with constant stirring and heating to 75-80° was gradually added 5 g of pyridine complex of copper tetraphenyl boron *. The solution was filtered and treated with 10% acetic acid, washed with water, 10% alkali, and again with water. The toluene was distilled off in vacuo. The crystalline residue was washed with cold alcohol and recrystallized twice from alcohol. 1.75 g (70%) of α-benzhydrylacetoacetic ester was obtained, m.p. 83-84°. A test mixture with benzhydrylacetoacetic ester made from Na-acetoacetic ester and diphenylbromomethane gave no depression of the melting point.

b) The experiment was performed in an atmosphere of nitrogen. To 2.25 g of benzalacetoacetic ester in 20-25 ml of toluene with constant stirring and heating to 75-80° was gradually added 5 g of the pyridine complex of copper tetraphenyl boron. The brown deposit which was thrown down was filtered off, washed with toluene, and with ether. The toluene was distilled off in vacuo. The residue, when it had crystallized, was washed with cold alcohol and recrystallized from alcohol. 1.77 g (70%) of α-benzhydrylacetoacetic ester was obtained, of m.p. 83-84°.

The precipitate which was filtered off, which weighed 0.51 g contained 96% of copper metal. The precipitate was dissolved in concentrated HNO_3, oxides of nitrogen being evolved, and in concentrated H_2SO_4, sulfur dioxide being produced.

2) With benzalacetylacetone. The experiment was carried out under the same conditions as above. 2.03 g of benzalacetylacetone was taken and 5 g of the pyridine complex of copper tetraphenyl boron. After 2 recrystallizations from alcohol 1.15 g (61%) of α-benzhydryl-α-acetylacetone was obtained, of m.p. 115.5°. Literature data: m.p. 116°C [6].

3) With benzalbenzoylacetic ester. The experiment was carried out as above. 1.63 g of benzalbenzoyl-acetic ester and 2.75 g of the pyridine complex of copper tetraphenyl boron were taken. After recrystallizing from 75% alcohol and washing with 50% aqueous alcohol 1.38 g (98%) of benzhydrylbenzoylacetic ester was obtained, of m.p. 135°C. Literature data: m.p. 135°C [6].

4) With α-ethylidenacetoacetic ester. To 17.2 g of α-ethylideneacetoacetic ester in 20-25 of toluene was added, with constant stirring and heating to 75-80°, 19.15 g of the pyridine complex of copper tetraphenyl boron (in this case a four-fold excess of the carbonyl compound over the theoretical was used, if we assume that only one phenyl group from the copper tetraphenyl boron takes part in the reaction). Addition completed, solution was cooled, filtered, treated with 10% acetic acid, washed with water, 10% alkali, and again water. The toluene was distilled off in vacuo. The liquid residue was distilled twice in vacuo. 6.88 g (107%) of α-phenethylacetoacetic ester was obtained, of b.p. 125.5—126° (4.5 mm); n_D^{20} 1.4990.

The constants of the α-phenethylacetoacetic ester obtained from Na-acetoacetic ester and α-bromoethyl-benzene are as follows: b.p. 125.5—126° (4.5 mm); n_D^{20} 1.4992.

5) With benzalacetophenone. The conditions were as in 1), but with the following difference: the heating was carried out on a boiling water bath. 2.25 g of benzalacetophenone was taken, and 5 g of the pyridine complex of copper tetraphenyl boron. After recrystallizing twice from alcohol 0.75 g (29%) of β,β-diphenyl-propiophenone was obtained, of m.p. 96-96.5°. A test mixture with a known specimen of β,β-diphenylpro-piophenone gave no depression of the melting point.

Literature data: m.p. 96°C [7].

6) With dibenzalacetone. 0.68 g of dibenzalacetone was placed in a test tube. After heating to 160°C on a glycerol bath 1 g of the pyridine complex of copper tetraphenyl boron was added gradually, with stirring. Ether was then added to the reaction mixture. The ether solution was washed with 10% acetic acid, water, 10% alkali, and again with water. The ether was evaporated off. The crystalline residue was twice recrystallized from alcohol. 0.19 g (42%) of α-benzhydryl-α-benzalacetone was obtained, of m.p. 136-136.5°. Lit. 136° [8].

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* In this case, as in the others, a 50% excess of the carbonyl compound was taken, on the assumption that only one phenyl from the copper tetraphenyl boron would undergo addition.

II. An attempt to combine a phenyl group from copper tetraphenyl boron with benzaldehyde.

To 1.14 g of benzaldehyde in 20-25 ml of toluene, which was heated to 75-80°, was gradually added with stirring 5 g of the pyridine complex of copper tetraphenyl boron. The toluene solution was then filtered, treated with 10% acetic acid, washed with water, 10% alkali, again with water, and treated with a solution of $NaHSO_3$. A deposit of the bisulfite compound of benzaldehyde was formed. The toluene was distilled off in vacuo. The residue was washed with alcohol and recrystallized from alcohol. The diphenyl obtained (0.71 g) had a m.p. of 68.5°. A test mixture with a known specimen of benzaldehyde melted at the same temperature.

The reactions of copper tetraphenyl boron with benzophenone and dibenzoylethylene also failed to give products from the addition of phenyl to these ketones.

III. Reaction between copper tetraphenyl boron and carbon tetrachloride.

The reaction was carried out in an atmosphere of dry pure nitrogen.

To 35-40ml carbon tetrachloride, heated to 75°C, was gradually added 7.5 g of the pyridine complex of copper tetraphenyl boron, with constant stirring. The precipitated brown substance, which contains the compound of pyridine with triphenylboron and copper salts, was filtered off, and washed with carbon tetrachloride and ether. The carbon tetrachloride was evaporated off. The residue was hydrolyzed * by heating for 2 hours with 1.1 g of calcium hydroxide and 0.7 g of powdered iron. The hydrolysis gave benzoic acid: after double distillation it had a m.p. of 121.5°. A test mixture with a specimen of known benzoic acid melted at the same temperature.

The pyridine/triphenyl boron compound was extracted from the brown precipitate with acetone. The part of the precipitate which did not dissolve in the acetone dissolved in water; on adding KI, CuI was precipitated and iodine evolved. Fromacetone filtrate, pyridine/triphenyl boron compound was obtained on adding water: this was recrystallized from an acetone/alcohol mixture. M.p. 212—218° (dec).

Literature data: m.p. 214 C° (dec) [9].

SUMMARY

It has been shown that copper tetraphenyl boron can react with α,β-unsaturated carbonyl compounds: the phenyl radical undergoes addition in the 4-position, and saturated carbonyl compounds are formed. The mechanism of this reaction is discussed.

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* Under conditions such that benzotrichloride is hydrolyzed to benzoic acid.

THE SYNTHESIS OF β-CHLOROALKYLAMINO DERIVATIVES OF THIAZOLE

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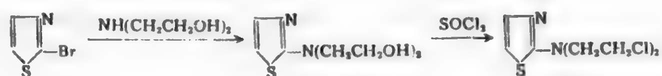
The β-chloroalkylamino derivatives of different classes of compounds to a large extent are biologically active, and in many cases have an anti-cancer activity.

The present paper describes the preparation of compounds of this type in the thiazole series. The derivatives of thiazole with a haloalkylamino group in the nucleus were made from 2-bromothiazole, in which the halogen is adequately active, and which on heating with diethanolamine in solution in pyridine is transformed to 2-di (β-hydroxyethyl)-aminothiazole, (I). By the action of thionyl chloride in solution in chloroform on (I) we obtained a 38% yield of 2-di(β-chloroethyl)-aminothiazole, (II).



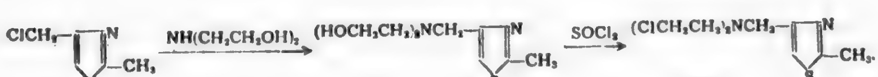
(I) (II)

Compounds with bis-β-chloroethylamino groups in the side chain were obtained in the cases of the 4- and 5-positions in the thiazole nucleus.

The general route for synthesizing these compounds consists in condensing an alcoholic solution of diethanolamine with the appropriate chloroalkyl derivative, subsequently replacing the hydroxyl groups with chlorine, using thionyl chloride. In this way a 31% yield of 4-di(β-hydroxyethyl)-aminomethylthiazole (III) was obtained from 4-di-(β-chloroethyl)-aminomethylthiazole (IV).

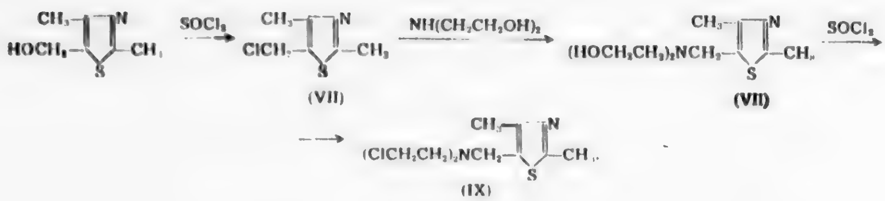
(III) (IV)

2-Methyl-4-di(β-hydroxyethyl)-aminomethylthiazole (V) was synthesized in 48.5% yield from 2-methyl-4-chloromethylthiazole, and on chlorinating (V) an 89.5% yield of 2-methyl-4-di(β-chloroethyl)-aminomethylthiazole; (VI) was obtained.

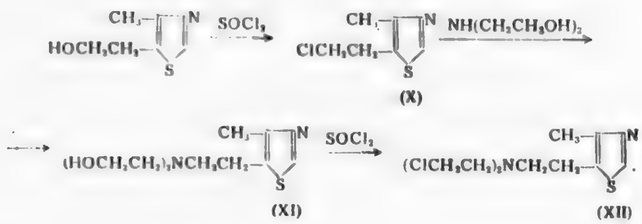


(V) (VI)

The parent compounds for the synthesis of 2,4 dimethyl 5-di(β-chloroethyl)-aminomethylthiazole was 2,4-dimethyl-5-chloromethylthiazole, (VII), which was made by chlorination of 2,4- dimethyl-5-hydroxymethylthiazole. The condensation of (VII) with diethanolamine takes place quite smoothly, giving the corresponding dihydroxyamino derivative, (VIII), which on chlorination gives 2,4-dimethyl-5-di(β-chloroethyl)-aminomethylthiazole, (IX).



The bis-β-chloroethylamino compound (position 5), with a longer side-chain, was made from 4-methyl-5-(β-chloroethyl)-thiazole, in accordance with the scheme given below:



EXPERIMENTAL

2-Di(β-hydroxyethyl)-aminothiazole, (I). A mixture of 32.8 g of 2-bromothiazole [1], 41.6 g of diethanolamine and 50 ml of pyridine was heated on a glycerol bath at 120-130° for ten hours. The pyridine and the unreacted 2-bromothiazole were distilled off in vacuo, the residue was dissolved in 100 ml of water, and the solution saturated with potash. The oily layer was separated and repeatedly extracted with ether. The ether was distilled off, and the residue distilled in vacuo. The substance boiled at 194-196° and 2 mm. The yield was 10.2 g. The hydrochloride of the amine had a m.p. of 129.5-130°.

Found %: C 37.34%, H 5.86%, N 12.99%. $C_7H_{13}O_2N_2SCl$ gives: C 37.58%, H 5.85% N 12.58%.

2-Di-(β-chloroethyl)-aminothiazole, (II). To a mixture of 6 ml of thionyl chloride and 6 ml of chloroform, cooled to -10°C in a four-necked flask fitted with a stirrer, was very slowly added (drop by drop) 7.5 g of 2-di(β-hydroxyethyl)-aminothiazole in 15 ml $CHCl_3$. Addition completed, it was stirred 30 min. and stood at room temperature till next day. After boiling for 3 hours the solvent was distilled off, and the oily residue was dissolved in anhydrous ethanol, the solution was treated with wood charcoal, and filtered. The filtrate, which was much lighter in color, was concentrated: on standing, crystals of the hydrochloride of 2-di-(β-chloroethyl)-aminothiazole were deposited. The salt was washed with acetone: m.p. 113.5–114°. The yield was 38%.

Found %: C 32.54%, H 4.08%, $C_7H_{11}N_2SCl_3$ gives: C 32.13%, H 4.24%.

4-Di-(β-hydroxyethyl)-aminomethylthiazole. (III). A mixture of 20 g of 4-chloromethylthiazole hydrochloride [2], 37.1 g of diethanolamine and 150 ml of anhydrous ethanol was heated for 20 hours on a water bath. The solvent was then distilled off, the residue dissolved in water, and the solution saturated with caustic soda. The oily layer was repeatedly extracted with benzene. The solvent was distilled off, and the residue distilled. The distillate was a light-yellow oil, of b.p. 195-197° at 5 mm. The yield was 7.35 g (31%).

Found %: C 47.74%, H 7.17%, $C_8H_{14}O_2N_2S$ gives: C 47.49%, H 6.98%.

The picrate of the amine, made by mixing alcohol solutions of the amine and picric acid, had a m.p. of 102-104°.

4-Di-(β-chloroethyl)-aminomethylthiazole (IV). 2.7 g of 4-di-(β-hydroxyethyl)-aminomethylthiazole was chlorinated with 3.2 g of thionyl chloride by the method described for making 2-di(β-chloroethyl)-aminothiazole, (II).

The crystalline, strongly hygroscopic hydrochloride of 4-di-(β-chloroethyl-aminomethylthiazole with m. p. 207-208° (dec.) was obtained in a yield of 0.8 g (22%).

Found %: C 34.75%, H 4.91%, N 10.38% $C_8H_{13}N_2SCl_3$ gives: C 34.85%, H 4.75%, N 10.15%.

2-Methyl-4-di-(β-hydroxyethyl)-aminomethylthiazole, (V). 2-Methyl-4-di(β-hydroxyethyl)-aminomethylthiazole was obtained from 31.3 g of 2-methyl-4-chloromethylthiazole [3] and 44.5 g of diethanolamine in solution in 100 ml of anhydrous ethanol by the method described for 4-di(β-hydroxyethyl)-aminomethylthiazole (III), on heating for 9 hours. The yield of the thick slightly yellowish oil, of b.p. 192-194° at 4 mm, was 28.3 g (48.5 %).

Found %: C 49.63%, H 7.66%, N 13.10 , $C_9H_{16}O_2N_2S$ gives: C 49.97%, H 7.45%, N 12.94%.

2-Methyl-4-di-(β-chloroethyl)-aminomethylthiazole, (VI). 4.3 g of 2-methyl-4-di-(β-hydroxyethyl)-aminomethylthiazole was chlorinated with 5 g of thionyl chloride, as described for 2-di-(β-chloroethyl)-aminothiazole, (II). The crystalline deposit obtained after distilling off the solvent was treated with anhydrous ethanol and filtered. M.p. 217-220° (dec); the yield was 5.8 g (89.5%). After purifying the alcohol solution with wood charcoal the substance had a m.p. of 223-224.5°, and, as analysis showed, it was the dihydrochloride of 2-methyl-4-di-(β-chloroethyl)-aminomethylthiazole.

Found %: C 33.08%, H 5.19%, N 8.49% Cl 42.96%, $C_9H_{16}N_2SCl_4$ gives: C 33.14%, H 4.94%, N 8.59% Cl 43.48%.

2,4-Dimethyl-5-chloromethylthiazole, (VII). To a solution of 10 g of 2,4-dimethyl-5-hydroxymethylthiazole [4] in chloroform, cooled to -5°C was added a chloroform solution of thionyl chloride, with cooling and stirring. When all the thionyl chloride had been added the reaction mixture was stirred and cooled for a further hour, and then left at room temperature till the following day. It was then heated to boiling for 2 hours; the solvent was distilled off; the residue was dissolved in water and the solution saturated with potash. The oily layer which separated was extracted with ether, the ether was distilled off, and the crystalline residue treated with a small amount of anhydrous ethanol and filtered. The melting point of the substance was 60-63°, the yield was 59%. After crystallizing from anhydrous ethanol the 2,4-dimethyl-5-chloromethylthiazole formed snow-white needles of m.p. 61-63%.

Found %: C 44.77%, H 5.16%, N 8.66%, C_6H_8NSCl gives: C 44.57%, H 4.99% N 8.66%.

2,4-Dimethyl-5-di(β-hydroxyethyl)-aminomethylthiazole, (VIII). This was made from 5.7 g of 2,4-dimethyl-5-chloromethylthiazole and 7.5 g of diethanolamine in the same way as for 4-di(β-hydroxyethyl)-aminomethylthiazole (III), on heating for 10 hours. The substance was a light yellow oil of b.p. 205-207° at 4 mm; n^{20}_D 1.5455. The yield was 5.5 g (63.7 %).

Found %: C 52.29%, H 7.84% $C_{10}H_{18}O_2N_2S$ gives: C 52.14%, H 7.87%.

2,4-Dimethyl-5-di(β-chloroethyl)- aminomethylthiazole, (IX). 2,4-Dimethyl-5-di(β-hydroxyethyl)-aminomethylthiazole (3.9 g) was chlorinated with thionyl chloride (4.0 g) by the method described for making 2-di-(β-chloroethyl)-aminothiazole, (II). The dihydrochloride of 2,4-dimethyl-5-di(β-chloroethyl)-aminomethylthiazole was obtained with a m.p. of 164-165° in a yield of 2.25 g (44%).

Found %: C 35.32%, H 5.36%, N 7.8%. $C_{10}H_{18}N_2SCl_4$ gives: C 35.30%, H 5.33%, N 8.23%.

4-Methyl-5-(β-chloroethyl)-thiazole, (X). To a chloroform solution of 20 g of 4-methyl-5-(β-hydroxyethyl)-thiazole [5], cooled to -5°C in a four-necked flask fitted with a stirrer, was added drop by drop a chloroform solution of 16.8 g of thionyl chloride. When all the reagent had been added the brown uniform reaction mass was stirred with cooling for a further hour, and then left to stand till the following day at room temperature. It

was then boiled for two hours, the solvent was distilled off, the residue was dissolved in water and the solution saturated with potash. The oily layer which separated was extracted with ether, the ether was distilled off, and the residue distilled in vacuo. B.p. 97-98° at 6 mm. The substance was obtained in a yield of 14.9 g (66%).

Found %: C 44.64%, H 5.10%. C_6H_8NSCl gives: C 44.57%, H 4.98%.

From Literature data [6]: 4-methyl-5-(β-chloroethyl)-thiazole has a b.p. of 74-75° at 3 mm.

4-Methyl-5-di-(β-hydroxyethyl)-aminoethylthiazole, (XI). This was obtained from 15 g of 4-methyl-5-(β-chloroethyl)-thiazole and 19.5 g of diethanolamine in alcoholic solution as in the case of 4-di-(β-hydroxyethyl)-aminomethylthiazole, (III), on heating for 30 hours. The substance was a thick yellow oil of b.p. 206-208° at 4 mm; n^{20}_D 1.5518. The yield was 8.0 g (37.5%)

Found %: C 51.91%, H 7.75% $C_{10}H_{18}O_2N_2S$ gives: C 52.14%, H 7.87%.

The picrate of 4-methyl-5-di(β-hydroxyethyl)-aminoethylthiazole was obtained from an alcohol solution in the form of lustrous yellow needles of m.p. 132-133°.

Found %: C 41.57%, H 4.53% N 15.00% $C_{16}H_{21}O_9N_5S$ gives: C 41.82%, H 4.61% N 15.24%.

4-Methyl-5-di-(β-chloroethyl)-aminoethylthiazole, (XII). A solution of 3 g of 4-methyl-5-di-(β-hydroxyethyl)aminoethylthiazole in chloroform in a four-necked flask fitted with a stirrer was cooled to -5°C and saturated with dry hydrogen chloride. A chloroform solution of 6.2 g of thionyl chloride was then added slowly, drop by drop. When all the reagent had been added the reaction mass was heated for 2 hours (until the evolution of hydrogen chloride ceased), the solvent was distilled off, the residue dissolved in anhydrous ethanol, treated with wood charcoal and filtered. The filtrate, which was much lighter in color, was concentrated, and on standing a crystalline salt of m.p. 175-178° was deposited: weight 4.7 g (48.7%). After an additional recrystallization from anhydrous ethanol the substance melted at 178-180°. This substance, as was shown by analysis, was the dihydrochloride of 4-methyl-5-di-(β-chloroethyl)-aminoethylthiazole.

Found %: C 35.58%, H 5.11%, N 7.89% $C_{10}H_{18}N_2SCl_4$ gives: C 35.3% H 5.33%, N 8.23%.

CONCLUSIONS

1. The introduction of a bis-β-chloroethylamino group into the side chains of thiazole nuclei in the 4- and 5-positions may be carried out by condensing the appropriate haloalkyl derivative with diethanolamine, the hydroxyamine so obtained being subsequently chlorinated.

2. A bis-β-chloroethylamino group was introduced only into the 2-position of the thiazole nucleus, as a consequence of the relative activity of halogen in the 2- position. In this case the hydroxyamine was made in pyridine solution.

3. A number of bis-β-hydroxyethylamino and bis-β-chloroethylamino derivatives of thiazole have been prepared.

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* T. p. = C. B. Translation pagination.

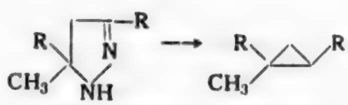
REACTIONS OF HYDRAZINE DERIVATIVES

XI. SYNTHESIS OF SOME CYCLOPROPANE HYDROCARBONS

I. I. Grandberg, A. N. Kost, and A. P. Terentyev

A number of aliphatic and alicyclic pyrazolines have been described [1,2]. Decomposition of these pyrazolines was carried out in the present work in order to obtain cyclopropane hydrocarbons. Decomposition of low-boiling pyrazolines was conducted in an autoclave at 250-350° for a period of 3-5 hours in the presence of lithium hydroxide. The usual method was used for the high-boiling pyrazolines (that is, slow distillation over alkali).

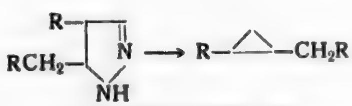
Conversion of alkyl pyrazolines into the corresponding cyclopropanes was discovered by N. M. Kizhner [5]. We have extended the use of the reaction. A 3-hour heating period up to 250-300° is sufficient for complete decomposition of 3,5,5-trialkylpyrazoline.



$R = CH_3$ (I); C_2H_5 (II); n-C_3H_7 (III).

In the simpler case, in the synthesis of 1,1,2-trimethylcyclopropane (I) we were able to change the method of synthesis with the result that the yield of this hydrocarbon reached 81.2%, with reference to the starting material, mesityl oxide; this is much higher than was described earlier in [3,4].

During the decomposition of 4,5-dialkylpyrazolines by the Kizhner method it was found that these compounds need a longer heating period (5-7 hours at 300-350°), and the yields of 1,2-dialkylcyclopropanes are low, since in the process of reaction condensation side products are observed.



$R = C_2H_5$ (IV); $CH(CH_3)_2$ (V).

4,4-Dimethyl-5-isopropylpyrazoline could not be converted into the corresponding cyclopropane hydrocarbon even when heated for 10 hours up to 400 deg. In this case nitrogen was not given off, the reaction mixture had an ammonia odor and when it was distilled a mixture of high boiling condensation products containing nitrogen was obtained.

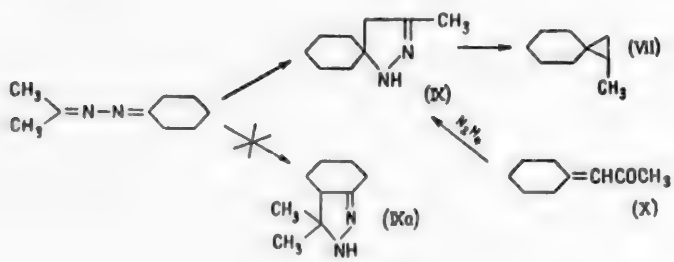
Great difficulties were encountered in purification of the hydrocarbon products, and this is in agreement with the work of N. M. Kizhner [5] and S. S. Nametkin [6]. Earlier [7] we obtained 1,1-pentamethylenebicyclo-(0,1,4)-heptane (VI), which, after being washed to remove remnants of pyrazoline and distilled over sodium, contained admixtures of the olefin (according to data of spectroscopic analysis *).

* The Raman spectra were analyzed by V. T. Aleksanyan and Kh. M. Sterin, commission on spectroscopy, Acad. Sci. USSR.

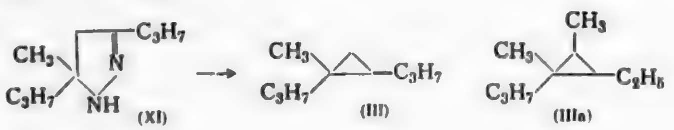
Purification by perbenzoic acid did not noticeably increase the purity of the compound. Then purification by a solution of copper acetate in acetic acid (to remove pyrazoline and other nitrogen-containing compounds) and performic acid was carried out.

1,1,-Pentamethylene-2-methylcyclopropane (VII) purified by the same method, when examined spectroscopically did not reveal any olefin impurity; hydrocarbons (VI) and 1,1-tetramethylenebicyclo-(0,1,3)-hexane (VIII) continued to contain negligible amounts of impurities of olefins; hydrocarbon (IV) contained a considerable amount of the olefin. Further purification was carried out by oxidizing the hydrocarbons with saturated aqueous solution of permanganate. This reagent oxidizes both cyclopropane hydrocarbons and the olefins, but the reaction proceeds much faster with the latter. Such purification of hydrocarbons (II), (III), (VII) and (VIII) gave pure compounds (although during purification large amounts were lost). 1-Ethyl-2-propylcyclopropane even after oxidation by permanganate contained a large quantity of olefin impurity. It is necessary to point out that the percentage of olefin impurity contained in 1,2-dialkylcyclopropanes was higher than in 1,1,2-trialkylcyclopropanes. This is most likely due to the cruder synthesis conditions of the former.

The hydrocarbon products (II), (III), (IV) and (V) could have cis- and trans-isomers (such isomerism is not possible for the other compounds), but their separation could not be achieved. After purification from the olefins, all the hydrocarbons obtained were distilled at intervals not greater than 0.5 degrees, and only 1-isopropyl-2-isobutylcyclopropane (V) boiled within an interval of 2 degrees. We then fractionally distilled this compound in the column; however, the bulk of hydrocarbon distillate distilled over in a 0.3° interval. Earlier [2] we described a pyrazoline compound which was obtained by rearrangement of a mixture of acetone, azine and cyclohexanone. Depending on the course of the reaction the compound can have either the structure (IX) or (IXa).



To prove the structure of this pyrazoline we synthesized 3-methyl-5,5-pentamethylenepyrazoline (IX) from acetone cyclohexylidene (X) and hydrazine. The pyrazoline obtained in this way had the same constants as that obtained from mixed pyridine. By decomposition of pyrazoline (IX) we obtained a hydrocarbon (VII) (systematic name*: 7-methylbicyclo-[6(8x, 1)]-octane). In this manner we confirmed by the use of pyridines the previously mentioned hypothesis, proved by us [2], that cyclization of pyridines into pyrazolines proceeds mainly through the methyl and not the methylene group. Because of this we believe that methylpropylketone azine [2] after rearrangement gives 5-methyl-3,5-dipropylpyrazoline (XI), and then, after its decomposition according to Kizhner, 1-methyl-1,2-dipropyl-cyclopropane (III) is formed and not 1,3-dimethyl-1-propyl-2-ethyl-cyclopropane (IIIa).



* Systematic nomeclature and numbering of atoms in cyclic compounds are given in [12].

In the literature there are some data concerning three of the seven cyclopropane hydrocarbons obtained in this work; for 1,1,2-trimethyl-cyclopropane (I) the constants of the spectroscopically pure compound are known [4]. 1-Methyl-1,2-diethylcyclopropane (II), was obtained in 1912 by N. M. Kizhner [8] using the same method, that is, from 5-methyl-3,5-diethylpyrazoline; however, it could not be adequately purified from the olefins. The same can be said about 1,1-tetramethylenebicyclo-(0,1,3)-hexane, obtained in 1930 by N. D. Zelinsky and N. I. Shuikin [9] by pyrolysis of cyclopentylidene cyclopentanone hydrazone.

We have obtained this hydrocarbon by decomposition of pure 3,4-trimethylene-5,5-tetramethylenepyrazoline [10] and we have purified it.

Our constants for hydrocarbon (I) coincide well with the data of B. A. Kazansky [4]; as for hydrocarbons (II) and (VIII), there was no essential variation in the refraction indices from those given in the literature; however, the density of the compound purified from the olefins was much higher than in the case of the compound not purified from the olefins which coincided with that in the literature. The same was observed for other cyclopropane hydrocarbons, where the refractive index practically did not change after purification from the olefins, and the increase in density was considerable.

EXPERIMENTAL

Cyclohexylidene acetone (X). To 45 g of sodium in 600 ml of anhydrous alcohol, 260 g of acetoacetic ester and 196 g of cyclohexanone were added, and the mixture boiled for 30 hours. Then 1600 ml of water was added and boiling was continued for 3 hours. The reaction mixture was extracted carefully with ether, the ether extracts were washed with 5% formic acid, water, dried with potassium carbonate and distilled. The fraction which boiled at 60-110 deg (20 mm) was fractionally distilled 4 times. The fraction with b.p. of 83-84 deg (12 mm) was pure cyclohexylidene acetone.

n^{20}_D 1.4759, d^{20}_4 0.9378, MR_D 41.56; calc. 41.10.
Semicarbazone - m.p. 145° (from alcohol).
Semicarbazone - m.p. 145° (from alcohol) [11].
Literature data: b.p. 84-88° (17 mm). $n^{17.6}_D$ 1.47555, d 0.94053.

3-Methyl-5,5-pentamethylenepyrazoline (IX). 41.4 g of cyclohexylidene acetone in 25 ml of butyl alcohol and 15.6 g of 96% hydrazine hydrate were boiled for 6 hours. The reaction bulk was evaporated from 100 ml of hydrochloric acid, alkalized with ammonia, and extracted with ether. The ether extract was dried with potassium carbonate and then evaporated. 29.7 g of 3-methyl-5,5-pentamethylene pyrazoline was obtained (71.8%).

B. p. 111-112° (15 mm), 104° (10 mm), 98° (8 mm), 95° (7 mm); n^{20}_D 1.4976, d^{20}_4 0.9873, MR_D 45.18; calculated 45.23 *.
N-Phenyl carbamide derivative, m.p. 123.5°
Found %: C 71.09, 71.14; H 7.79, 7.83. $C_{16}H_{21}ON_3$. Calculated %: C 70.83; N 7.80. N-Acetyl derivative, m.p. 86° (in 40% alcohol).

The pyrazoline compound obtained from the mixture of acetone, pyridine and cyclohexanone [2], had the following constants:

126-127° (22 mm), 112° (15 mm), n^{20}_D 1.4979, d^{20}_4 0.9865. n-Phenylcarbamide derivative - m.p. 123° (from alcohol). A mixture with the above-mentioned compound had a m.p. of 123.5 deg. N-Acetyl derivative - m.p. 86 deg. (from 40% alcohol); a mixture with the above-mentioned compound had a m.p. of 86 deg.

Found %: N 14.51, 14.54. $C_{11}H_{18}ON_2$. Calculated %: N 14.42.

1-Methyl-1,2-diethylcyclopropane (II). A mixture of 24 g of 5-methyl-3,5-diethylpyrazoline [2] and 5 ml of 5% lithium hydroxide solution was placed into an autoclave of 150 ml volume and then heated for 3 hours (250-300°). The reaction mixture was then stirred energetically for a period of 3 hours with 150 ml of a solution of 20 g of copper acetate in 10% acetic acid. The hydrocarbon was then extracted with ether and the ether extract was quickly mixed with the use of a stirrer, with a solution containing 50 ml of 85% formic acid and 30 ml of 30% hydrogen peroxide, for a period of 5 hours. After the addition of 100 ml of water, the ether layer was separated, washed with sodium carbonate, dried, and distilled. 10.8 g (56.4%) of

* Refraction for bi-atomic nitrogen in pyrazoline equals 5.871 [1, 2].

the hydrocarbon was obtained, m.p. 106.7-107.6° (740 mm); n_D^{20} 1.4102. The hydrocarbon was shaken with a saturated solution of potassium permanganate at 5-10 deg (enough permanganate should be used to oxidize 30% of the hydrocarbon). Finally the reaction mixture was steam distilled, and the distillate was extracted with ether, dried with metallic sodium, and then distilled over sodium.

The bulk of 1-methyl-1,2-diethylcyclopropane had the following constants:

b. p.: 107.4° (741 mm), n_D^{20} 1.4100, d_4^{20} 0.7412, MR_D 37.52; Calc. 37.65.
Found %: C 85.71, 85.68; H 14.36, 14.41. C_8H_{16}. Calculated %: C 85.64; H 14.36.
Literature data: 108-109° (742 mm), n_D^{20} 1.4102. d_4^{20} 0.7382 [8].

The hydrocarbons given below are obtained in ananalogous way.

1-Ethyl-2-propyl cyclopropane (IV) was obtained when 62 g of 4-ethyl-5-propyl pyrazoline was heated for 5 hours at 320 deg [1]. After purification with performic acid, 22.3g (45%) of a fraction was obtained, with b.p. 116.5-117.5° (741 mm), n_D^{20} 1.4119. The hydrocarbon, after purification with permanganate, had the following constants:

b. p.: 116.6° (741 mm), n_D^{20} 1.4118, d_4^{20} 0.7354, MR_D 37.95; Calc. 37.65.
Found %: C 85.44, 85.51; H 14.41, 14.47. C_8H_{16}. Calculated %: C 85.64; H 14.36.

2-Methyl-1,1-pentamethylenecyclopropane (VII) was obtained by heating 31 g of 3-methyl-5,5-pentamethylenepyrazoline [2] for 3 hours at 280 deg. After purification with performic acid, 13 g (52.5%) of a fraction was obtained, with b.p. 147.5-149° (760 mm), n_D^{20} 1.4526. After purification with permanganate, the hydrocarbon had the following constants:

p.: 145.5-145.9° (745.5 mm), n_D^{20} 1.4522, d_4^{20} 0.8367, MR_D 40.07; Calc. 40.06.
Found %: C 86.85, 86.87; H 13.06, 13.08. C_9H_{16}. Calculated %: C 87.04; H 12.96.

1-Methyl-1,2-dipropylcyclopropane (III) was obtained after heating 33.4 g of 5-methyl-3,5-dipropylpyrazoline [2] for 3 hours at 280 deg. After purification with performic acid, 19.6 g (70%) of the fraction was obtained, with the b.p. 153-154.5° (750 mm), n_D^{20} 1.4207. After purification with permanganate, the hydrocarbon had the following constants:

b.p.: 152.9-153.4° (749.6 mm), n_D^{20} 1.4210, d_4^{20} 0.7621, MR_D 46.67; Calc. 46.88.
Found %: C 85.68, 85.62; H 14.49, 14.43. $C_{10}H_{20}$. Calculated %: C 85.63; H 14.37.

1,1,2-Trimethylcyclopropane (I). 49 g of pure mesityl oxide, 31.2 g of 96% hydrazine hydrate, and 5 ml of 5 % lithium hydroxide solution were heated in an autoclave for 4 hours at 250-300 deg., and then the mixture was treated as directed above. After purification with performic acid, 34.1 g (82.1%) of a fraction was obtained with b.p. 51-55° (740 mm), n_D^{20} 1.3888. After purification with permanganate, the hydrocarbon had the following constants:

b.p.: 52.1-52.4° (742 mm), n_D^{20} 1.3879, d_4^{20} 0.6948, MR_D 28.57; Calc. 28.41.
Literature data: b.p. : 52.6° (760 mm), n_D^{20} 1.3862, d_4^{20} 0.6948[4].

1,1-Tetramethylenebicyclo-(0,1,3)-hexane (VIII).* Upon decomposition of 25 g of 3,4-trimethylene-5,5-tetramethylenepyrazoline [10] over 0.5 g of lithium hydroxide in an open vessel, and after the usual further treatment, the hydrocarbon was obtained in 88.8% yield, with b.p. of 183-185° (746 mm), n_D^{20} 1.4856. After purification with permanganate, the hydrocarbon had the following constants:

b.p.: 81° (80 mm). n_D^{20} 1.4848, d_4^{20} 0.9193, MR_D 42.45; Calc. 42.48.
Found %: C 88.27, 88.21; H 11.89, 11.92. $C_{10}H_{16}$. Calculated %: C 88.16, H 11.85.
Literature data: b.p.: 188-190°; n_D^{20} 1.4855, d_4^{20} 0.9140 [9].

* The systematic name is: tricyclo-[5(1,10x); 10-6]-decane [12].

1-Isopropyl-2-isobutyl cyclopropane (V). 187 g of 4-isopropyl-5-isobutylpyrazoline [1] and 5 g of lithium hydroxide were decomposed in an autoclave for 6 hours at a temperature of 340 deg. The reaction mixture was washed with 10% hydrochloric acid. The oily layer was treated with a mixture containing 100 ml of 30% hydrogen peroxide and 100 ml of 85% formic acid; the hydrocarbon was then separated, washed with sodium carbonate, water, dried with calcium chloride, and distilled. 80 g (57.1%) of a fraction with b.p. of 143-153 deg (740 mm) was obtained. The hydrocarbon was then shaken for 16 hours with a solution containing 50 g of potassium permanganate in 3 liters of water, steam distilled and the distillate extracted with ether. The ether extract was dried with potassium carbonate and after evaporation of the ether, the hydrocarbon was boiled with 1.5 g of metallic sodium for a period of 6 hours. During distillation 19 g of a hydrocarbon with b.p. 147-149° (740 mm), n_D^{20} 1.4177, d_4^{20} 0.7521. was obtained. 22.7 ml (18.2 g) of this hydrocarbon was distilled on a column containing 30 theoretical plates. The first 3 ml of the distillate had the b.p. 140-147.2° (742 mm), and the rest of the hydrocarbon (10 ml) distilled over at 147.2-147.5 deg. (742 mm);

n_D^{20} 1.4177, d_4^{20} 0.7508, MR_D 47.05; Calc. 46.88.

Found %: C 85.41, 85.53; H 14.47, 14.37. $C_{10}H_{20}$. Calculated %: C 85.63; H 14.37.

When the rest of the distillate was fractionally distilled, it had b.p. 148.2-149° (745 mm), n_D^{20} 1.4180, d_4^{20} 0.7526.

SUMMARY

Decomposition of some pyrazoline compounds over lithium hydroxide, following the method of N. M. Kizhner, has been studied. Some cyclopropane hydrocarbons were obtained.

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INTERACTION PRODUCTS OF β-PICOLINE AND 2,4-DINITROCHLOROBENZENE

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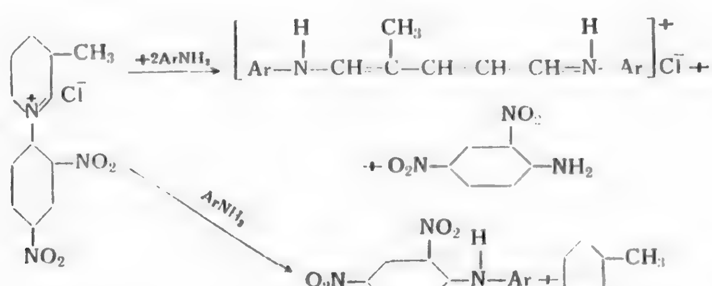
By analogy with the method used to prepare 2,4-dinitrochlorophenylate of pyridine, Zincke tried to obtain the corresponding salts of other heterocyclic types. [1], however, he was only able to obtain the 2,4-dinitrochlorophenylate of isoquinoline [2]. It has been pointed out in other works [3] that of all the pyridine homologs only β-picoline forms the corresponding salt with 2,4-dinitrochlorobenzene. One of us [4] was able to obtain the 2,4-dinitrochlorophenylate of α-picoline and also the products of its decomposition by aromatic amines and alkali. During condensation of α-picoline with dinitrochlorobenzene one could observe formation of a violet, tarry substance; its nature was not determined, but it was noticed that on storage the 2,4-dinitrochlorophenylate of α-picoline assumed a violet color, and finally the tarry substance formed. The appearance of the tarry, violet substance is also observed during condensation of 2,4-dinitrochlorobenzene with other pyridine homologs.

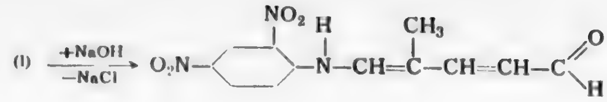
The subject of this work is the study of the products of interaction of 2,4-dinitrochlorobenzene and β-picoline. β-Picoline was selected because of the fact that the methyl group in the β-position of the quaternary pyridine salts has no ability to condense, and therefore it is easier to trace the mechanism by which the products are formed when the original compounds interact.

It is very difficult to obtain chemically pure β- and γ-picolines and the existing methods of their purification [5] do not guarantee high purity of the end products. The method used by us [6], gave us 98-99% purity. Condensation of dinitrochlorobenzene with β-picoline was conducted under various conditions — with and without a solvent, and under different temperature conditions. In all cases there were formed the 2,4-dinitrochlorophenylate of β-picoline and a violet substance, the amount of the latter increasing with increase of temperature and reaction time. There was no difficulty in identifying the dinitrochlorophenylate of β-picoline; the salt was obtained in a free state and its decomposition products were obtained – dianiline hydrochlorides of glutaconic dialdehyde (pyridine dyes), and the corresponding derivatives of 2,4-dinitrodiphenylamine:

(I)



and monoanil by the following reaction:

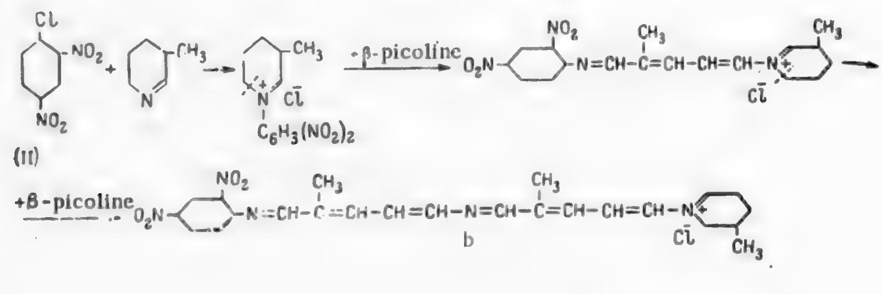


When the 2,4-dinitrochlorophenylate of β-picoline was analyzed, it was noticed that the violet substance forms during melting of the salt and also during evaporation of its aqueous solution; it forms with special ease when the salt comes into contact with the picoline. These observations allow us to believe that the violet substance is a product of the decomposition of β-picoline dinitrochlorophenylate by picoline. The above supposition seemed to be confirmed by the fact that when the violet substance was heated with hydrochloric acid and a small amount of dinitroaniline, a colorless 2,4-dinitrochlorophenylate of β-picoline was obtained. However, regardless of the mutual conversion of the salt and the violet substance, which points to the origin of the latter, some doubt about such a formation scheme of the violet substance was brought about by the deep color of the substance, since the pentamethine dye which is the decomposition product of the picolone salt by the picoline can possess an orange, but not a violet color. Further analyses have shown that the violet substance is a mixture of two products — a violet dye containing chlorine, and a brown compound containing no chlorine. By decomposition of the dye with hydrochloric acid and isolation of it 2,4-dinitroaniline it was proved that the dye molecule contains dinitrophenyl remnants. When the dye was decomposed with alkali in methyl alcohol, 2,4-dinitroanisole was obtained, which could form from dinitrochlorobenzene. When the alcohol solution of the dye was treated with an aqueous solution of sodium carbonate, the original compound was obtained. The color of the solutions of the original compound differed very little from that of the dye; it possesses solvatochromic properties; that is, it is an intraionic dye.

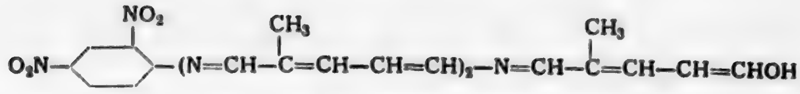
TABLE 1
Color Change of the Violet Dye (1) and its Original Compound (2)

No.	λ max. in acetone (mμ)	D max.	λ max. in acetone + NaOH (mμ)	D max.	λ max. in benzene (mμ)	D max.	λ max. in acetic acid (mμ)	D max.
1	560	1	580	1.7	540	0.9	520	0.4
2	560	2.3	595	3.5	550	1.3	520	2.0

Molecular weight determinations of this compound, and also its analysis, analyses of the violet dye and the brown compound, led us to accept the following formation scheme for the violet dye:

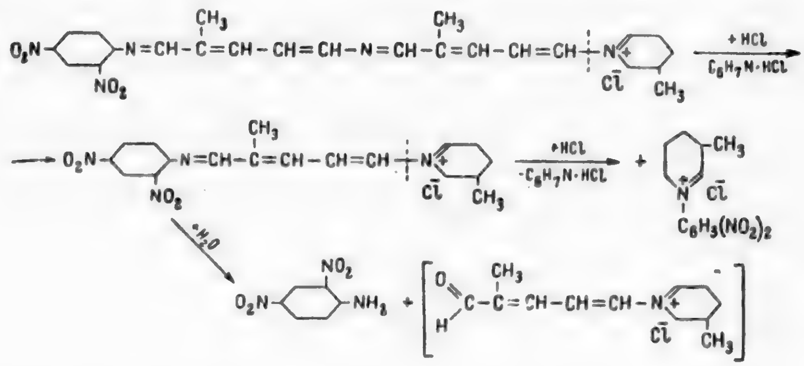


Remnants of dinitroaniline and also picoline remnants serve as perichromes in the dye of formula "b"; the character of the bonds of these remnants with the hydrocharbons differs. Only nitrogen of the picoline nucleus can be a carrier of the positive charge. With the help of such a formula the deep color of the compound and its instability can be explained. During treatment with sodium carbonate, the pyridine ring splits and the product can be expressed with the following formula:

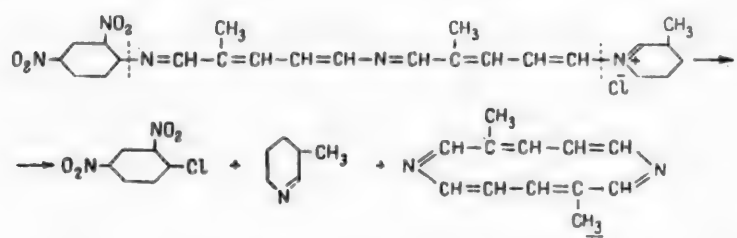


During the reaction of alkali and the dye, this compound, being unstable like the dye itself, does not form, but a hydrolytic decomposition into dinitroaniline and picoline takes place.

The violet dye, when dissolved in hydrochloric acid, takes on an orange color, and when the solution is heated the color changes to brown. One can thus propose the following scheme for the decomposition of the dye with hydrochloric acid:

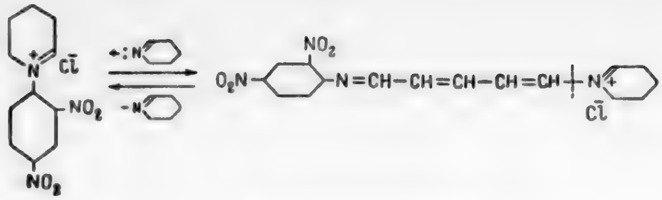


The nature of the brown substance which always accompanies the violet dye has not been definitely determined. As was already mentioned, the violet dye is very unstable and decomposes with special ease when in solution,the brown substance and dinitrochlorobenzole precipitating out of the solution when it is allowed to stand. Thus it seems that the brown substance is a product of decomposition of the violet dye; the decomposition most likely proceeds in the following manner:



However, it could also be a product of polymerization, in which the unsaturated chain containing five methine groups plus nitrogen repeats "X" times. The content of nitrogen in the brown substance was found to be approximately the same as that in picoline. The compound possesses the following properties — it dissolves in acids, it is soluble in pyridine and precipitates from it upon addition of ether and water.

The fact that the 2,4-dinitrochlorophenylate of β-picoline can be decomposed with heterocyclic types of compounds let us to believe that the corresponding pyridine salt can also be decomposed with the heterocyclic compounds. And it was found that when the orange solution of the 2,4-dinitrochlorophenylate was heated, the color of the solution changed to brown. No noticeable change in the salt was observed when the pyridine dinitrochlorophenylate was heated for a long time with pyridine, the greater part of the salt remaining unchanged. Small amounts of dinitroaniline and of the brown substance, which did not contain chlorine, were separated from the pyridine solution. When pyridine dinitrochlorophenylate and β-picoline are treated similarly, an unstable orange-red coloration appears, and with quinoline it gives a fuchsin color which disappears on heating. Thus it seems that the quaternary pyridine salt and also picoline salts can be decomposed by heterocyclic compounds, with the formation of unstable polymethine dyes; with pyridine the pentamethine dye forms most likely according to the reaction:



EXPERIMENTAL

Condensation of 2,4-dinitrochlorobenzene with β-picoline. β-Picoline was purified with cuprous chloride and a mixture of phthalic and acetic anhydrides [6]. The β-picoline fraction (b.p. 141 deg) was treated with cuprous chloride. The compound was obtained in the form of a dark-yellow paste which was washed several times in the mortar with benzene, and then on the filter with chloroform. The precipitate was dried and decomposed with excess alkali and the picoline was then distilled with water vapor. After separation and drying over potassium carbonate, picoline was heated on a net with 3 parts of phthalic and 2 parts of acetic anhydrides for a period of 6 hours. Such purification was conducted three times. No color was obtained when picoline, so purified was heated with phthalic anhydride; its b.p. was 144 deg. Its picrate melted at 152 deg.; with a microscope one could see yellowish green crystals in the form of small, notched sticks with an admixture of 1 to 2 leaf-like crystals. The 2,4-dinitrochlorobenzene, recrystallized from methanol, melted at 52°.

2,4-Dinitrochlorophenylate of β-picoline. Experiment 1. 5 g dinitrochlorobenzene was heated on a net and in the course of 1-1.5 minutes it dissolved into 2.6 ml of β-picoline. 20 ml of dry ethyl ether was added to the cool, dark brown solution, which then became a reddish-violet color; the solution was covered and left to stand for 24 hours (at 14°). A light violet precipitate came out and it was washed with dry ether until the reddish-violet coloration disappeared. Neither picoline nor dinitrochlorobenzene were detected in the last portions of ether. The salt — 2,4-dinitrochlorophenylate of β-picoline — an almost colorless crystalline substance had a m.p. of 160°; it was readily soluble in water, dissolved in methyl and ethyl alcohols, and was hygroscopic. The yield was 3.4 g (45.5%)

Experiment 2.5 g of 2,4-dinitrochlorobenzene and 4.35 g (2.6 ml) of β-picoline were heated together for 5 minutes at 90°. A thick, tarry mixture formed, with a shiny violet surface. When dry ether was added to the mixture, a dark, powderlike precipitate formed which dissolved partially during filtration. The ether solution had a reddish-violet color. The precipitate was washed several times with ether and then with water; the bulk of the precipitate dissolved with a brownish-red color. 3 g of the compound which did not dissolve in water was obtained. The water solution was made colorless and evaporated on a water bath; the picoline odor became more perceptible, and the salt darkened with the degree of evaporation of water. The picoline was extracted from the solution with benzene several times, and then the evaporation was conducted with addition of a small amount of hydrochloric acid; the salt thus obtained was almost colorless. The yield was 2.8 g.

The monoanil of β-methylglutaconic dialdehyde was obtained when the 2,4-dinitrochlorophenylate of β-picoline was decomposed with 15% aqueous alkali. After recrystallization from methyl alcohol, the reddish-brown, finely crystalline powder, with m.p. 161° was soluble in acetone, chloroform, ether and alcohol with a brown color, and less soluble in acetic acid. Upon addition of alkali, the color becomes fuchsin in alcohol, and blue-violet in acetone. The compound contained traces of the solvent.

Found %: N 14.78, 14.85. $C_{12}H_{11}O_5N_3$. Calculated %: N 15.16.

Decomposition of the 2,4-dinitrochlorophenylate of β-picoline with aromatic amines. When aromatic amines react with the 2,4-dinitrochlorophenylate of β-picoline, there form 2,4-dinitrochlorophenylamine derivatives together with the pyridine dyes (Scheme 1), which are obtained in small amounts. The condensation was conducted in an alcohol solution on a steam bath at 30-40°; the dyes were precipitated from alcohol with dilute hydrochloric acid, washed with benzene in order to purify them from dinitrophenylamine derivatives, and then crystallized from ethyl alcohol (Table 2).

TABLE 2

No.	The Dye, Amine derivative	Appearance of the dye	M. P.	λ Max. in ethyl alcohol (in mμ)	Analysis results
1	Aniline	Brown-red needles	145°	485	Found %: N 9.37. $C_{18}H_{19}N_2Cl$ Calculated %: N 9.44
2	p-Anisidine	Reddish-violet needles	142	495	Found %: N 7.83. $C_{20}H_{23}O_2N_2Cl$ Calculated %: N 7.81
3	p-Phenetidine	Blue-violet needles	130	495	Found %: N 7.53. $C_{22}H_{27}O_2N_2Cl$. Calculated %: N 7.24

The violet substance. A violet substance was obtained upon condensation of 2,4-dinitrochlorobenzene and β-picoline; this violet substance was soluble in pyridine, acetone, methyl and ethyl alcohol, and less soluble in acetic acid; however, it did not crystallize out of the mentioned solvents. When solutions of this compound were heated, a noticeable change in color took place; the solutions obtained a brownish tinge, indicating that the decomposition of the compound took place. We tried to purify the compound by dissolving it in cold methyl alcohol or acetone and then precipitating it with ether. We obtained a dark, almost black powder, which after standing in a desiccator over sulfuric acid, was microanalyzed for nitrogen and chlorine; m.p. 157° (from methyl alcohol), 169° (from acetone); it contained traces of the solvent.

Found %: N 13.48, 13.23; Cl 4.37, 4.46. $C_{24}H_{24}O_4N_5Cl \cdot \frac{1}{2}CH_3COCH_3$. Calculated %: N 13.71; Cl 6.97.

The compound was purified on a chromatographic column containing Al_2O_3. The compound was first treated several times with ether and then dissolved in cold acetone; the filtered solution was used in the column. There were two distinct zones: the upper one – brown, changing to yellow, and the lower one – violet. The violet substance was extracted with acetone, the acetone was driven off on a water bath (65°), and the rest of it was evaporated in vacuum. A dark violet substance with a green luster was obtained; m.p. 130°; it contained traces of the solvent. Chlorine test was positive.

Found %: N 13.67, 13.70; Cl 11.52, 12.00.

The compound was again heated in vacuum over P_2O_5 for 1 hour (50 mm, 76°); oily drops appeared on the walls of the drying case, and the compound became dull on the surface. The compound was treated several times in a mortar with dry ether, filtered, and then left in a vacuum desiccator. The ether had a slight red color, and after its evaporation a small amount of a dark, tarry substance remained. From it, dinitrochlorobenzene was extracted with benzene. After such purification the compound contained no solvent.

Found, in %: N 14.88, 14.98; Cl 7.53. $C_{24}H_{24}O_4N_5Cl$. Calculated %: N 14.54; Cl 7.37.

The brown substance – from the upper zone of the column – did not dissolve in acetone or in alcohols, but it was soluble in pyridine. It can be precipitated from pyridine with water and ether. When water was used, a dark brown powder was obtained which did not contain chlorine and did not melt; it was soluble in acids – in acetic acid with a faintly red color, and in hydrochloric acid with a brown color. It contained traces of the solvent.

Found, in %: N 14.67, 14.61. $C_{12}H_{14}N_2$. Calculated %: N 15.05.

The 2,4-dinitrochlorophenylate can also be decomposed with pyridine. 2 g of the 2,4-dinitrochlorophenylate of β-picoline and 4 ml of pyridine were heated for 5-7 minutes at 120°. An immediate red-violet coloration was obtained when pyridine was added to the salt; it became more intense during heating, but soon acquired a brown tinge. After cooling, the reaction mixture was diluted with ether; a dark, greasy precipitate formed, which was washed several times with water. Then it was washed on the filter with alcohol and ether. 0.43 g of a dark product was obtained; it was soluble in acetic acid with the red color, and in methyl alcohol and acetone – with a dirty red-violet color; soluble in dichloroethane and insoluble in benzene. It contained no chlorine. The product was purified by solution in acetic acid and precipitation with alkali; a black precipitate was obtained, which was washed many times with water and then dried in vacuum over P_2O_5 (50 mm, 76°); the precipitate contained traces of solvent. M.p. 168 - 171°.

Found %: N 14.72, 14.56. $C_{17}H_{19}N_3 \cdot H_2O$. Calculated %: N 14.84.

No noticeable decomposition of the salt occurred when 10 ml of pyridine and 4 g of the 2,4-dinitrochlorophenylate were heated at 130° for 4 hours. Insignificant amounts of 2,4-dinitroaniline and a brown substance which did not contain chlorine were separated from the pyridine solution.

Reactions of the violet compound. 1 g of the violet substance was treated in the cold with successive fresh portions of methyl alcohol until the alcohol was almost colorless. 0.55 g of the undissolved compound remained. The alcohol solution was treated with an aqueous solution of sodium carbonate. The color of the mixture turned from violet to brown, and a very fine, dark precipitate came out which was centrifuged and washed several times with water. 0.12 g of a black powder was obtained. A dark powder was obtained on reprecipitation from alcohol with water, m.p. 147° (with decomposition). It was soluble in alcohol and acetone with a violet color, and in acetic acid – with a fuchsin color. It did not dissolve in benzene or in dichloroethane.

Found %: N 15.81, 15.73. M 456, 468.5. $C_{24}H_{25}O_5N_5$. Calculated %: N 15.12 M 463.

When a hot solution of the violet substance in methyl alcohol was treated with a 15% aqueous solution of NaOH, a blue color appeared, but no precipitate formed. After the alcohol solution was diluted several times with water, clouding-up occurred and a light precipitate soon came out. The precipitate was washed several times with water and recrystallized with charcoal from 50% methyl alcohol; colorless, silky needles were obtained, m.p. 86°; the precipitate contained no chlorine and dissolved in alcohol and acetone. On addition of alkali to the acetone solution, the acetone layer turned an intensive blue color.

Found %: N 14.28, 14.17. $C_7H_6O_5N_2$. Calculated %: N 14.14.

When mixed with 2,4-dinitroanisole, no depression was observed.

SUMMARY

1. Interaction between β-picoline and 2,4-dinitrochlorobenzene has been studied. Three reaction products were separated and examined: 1) the 2,4-dinitrochlorophenylate of β-picoline; 2) a violet polymethine dye – product of the reaction of the 2,4-dinitrochlorophenylate of β-picoline and two molecules of β-picoline; 3) a brown compound – a decomposition product of the dye.

2. The nature of the violet dye was determined by analysis of the products of its decomposition with acid and alkali, and also by the mutual conversion of the dye and the 2,4-dinitrochlorophenylate of β-picoline. An opinion about the structure of the brown substance is expressed.

3. Four derivatives of β-picoline 2,4-dinitrochlorophenylate were obtained and examined: three hydrochlorides of β-methylglutaconic dialdehyde dianils – which are derivatives of aniline, p-anisidine, p-phenetidine, and the monoanil of β-methylglutaconic dialdehyde.

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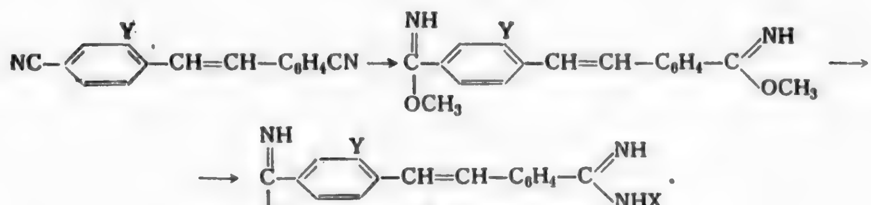
ALKYLATED DIAMIDINES OF THE STILBENE TYPE

I. M. Lipovich and S. I. Sergievskaya

It is known that the hydrochloride and isethionic salts of 4,4'-diamidino stilbene (stilbamidine) and also the hydrochloride salt of 4,4'-diamidino-2-hydroxystilbene have been recommended for the treatment of certain malignant growths [1]. However, these compounds could not be used effectively due to side effects. Thus we thought it useful to try to synthesize analogous compounds which would have better qualities as drugs. In the present work is given some information concerning alkylated diamidines of stilbene and 2-substituted stilbenes, which are not described in the literature; we hoped to lower the toxicity of the drugs by introducing alkyl groups into the amidine compounds.

Literature data concerning the synthesis of diamidines is very rich, and ways of obtaining the initial and intermediate materials necessary for the synthesis of diamidines have been described by many investigators. We have chosen the following method: from the corresponding dicyanostilbenes, the iminoethers were obtained by treating the former with ammonia or amines; the diamidines were also produced [2].



(I)

$Y = H, OH, NO_2, NH_2, Cl$ I $X = H, CH_3, C_4H_9, CH_2C_6H_5$ and others.

For the synthesis of the above-mentioned starting substances, we needed 4,4'-dicyanostilbene and 4,4'-dicyano-2-nitrostilbene. In the synthesis of 4,4'-dicyanostilbene we first prepared trans-4,4'-dinitrostilbene be reacting an alcoholic solution of potassium hydroxide with p-nitrobenzyl chloride [3]; 4,4'-diaminostilbene was then obtained by reduction of the above compound with stannous chloride and an ice solution of acetic acid containing hydrochloric acid [4]. Mainly 4,4'-diaminophenyl ethane was produced by a catalytic reduction in the presence of nicket as catalyst. Zandmayers method [5] was used for the conversion of 4,4'-diaminostilbene to 4,4'-dicyanostilbene, but with a slight modification: addition of the diazonium salt solution to the copper cyanide solution was done not with heating, but in the cold and with addition of benzene; this prevented foaming of the solution, which inhibits the reaction. 2-Nitro-4,4'-dicyanostilbene was obtained by reaction of p-cyanobenzaldehyde and o-nitrobenzyl chloride in the presence of piperidine [6,7]. Other 2-substituted 4,4'-dicyanostilbenes were obtained by the use of 2-nitro-4,4'-dicyanostilbene and 2-amino-4,4'-dicyanostilbene, as described in the literature [7]. Some data concerning the obtained diamidines are given in the table.

TABLE 1

Compound No.	Compounds			Yield (in %)	M. P. (in °C)	Analysis (in %)				
						found		calculated		
	name	meaning of X in the formula (I)	meaning of Y in the formula (I)			N	Cl	formula	N	Cl
1	4,4'-Di-(methylamidino)-stilbene. Dichlorohydrate	CH_3	H	64	Does not melt at 340°	14.92	-	$C_{18}H_{20}N_4 \cdot 2HCl$	15.34	-
2	4,4'-Di-(methylamidino)-2-hydroxystilbene. DC**	CH_3	OH	50	Does not melt at 320°	13.46	16.65	$C_{18}H_{20}N_4O \cdot 2HCl \cdot 2H_2O$	13.48	17.0
3	4,4'-Di-(butylamidino)-2-hydroxystilbene. DC**	C_4H_9	OH	43	309-311 (with decomposition)	11.96	15.05	$C_{24}H_{32}N_4O \cdot 2HCl \cdot H_2O$	11.60	14.70
4	4,4'-Di-(ethylamidino)-2-hydroxystilbene. DC**	$(C_2H_5)_2$	OH	31	300-302	-	14.70	$C_{24}H_{32}N_4O \cdot 2HCl \cdot H_2O$	-	14.70
5	4,4'-Diamidino-2-nitrostilbene.* DC**	H	NO_2	50	Does not melt at 320°	17.43	17.63	$C_{16}H_{15}N_5O_2 \cdot 2HCl \cdot H_2O$	17.50	17.75
6	4,4'-Di-(methylamidino)-2-nitrostilbene. DC**	CH_3	NO_2	47	320 (with decomposition)	15.76	17.00	$C_{18}H_{19}N_5O_2 \cdot 2HCl \cdot H_2O$	16.35	16.60
7	4,4'-Diamidino-2-aminostilbene*. Trichlorohydrate	H	NH_2	50	315-318 (with decomposition)	15.94	26.48	$C_{16}H_{17}N_5 \cdot 3HCl \cdot 2H_2O$	16.42	25.80
8	4,4'-Di-(methylamidino)-2-chlorostilbene. DC**	CH_3	Cl	50	Does not melt at 320°	13.00	25.33	$C_{18}H_{19}N_4Cl \cdot 2HCl \cdot H_2O$	13.41	25.50
9	4,4'-Di-(methylamidino)-2-iodostilbene. DC**	CH_3	I	50	Does not melt at 320°	11.18	-	$C_{18}H_{19}N_4I \cdot 2HCl \cdot H_2O$	11.00	-
10	4,4'-Di-(benzylamidino)-2-hydroxystilbene. DC**	$CH_2C_6H_5$	OH	35	314-316 (with decomposition)	10.22	13.31	$C_{30}H_{28}N_4O \cdot 2HCl \cdot H_2O$	10.19	12.88

* Compounds 5 and 7 were obtained by the action of a saturated solution of ammonia in anhydrous ethyl alchol on corresponding iminoethers.
** DC = Dichlorohydrate.

EXPERIMENTAL

To the ether suspension of 4,4'-di-(iminoether) stilbene or of the dichlorohydrate of a 2-substituted stilbene, alkylamine alcohol solution was added gradually with cooling.* After all was added, mixing was continued for 4 - 5 hours together with cooling, and the solution was left to stand overnight. The precipitate was filtered and dissolved with heating in water; to this solution charcoal was added and the whole then boiled for 20-30 min.; after boiling the solution was filtered again and 10% hydrochloric acid was added to the filtrate. After cooling the dichlorohydrate of diamine precipitated out. Dichlorohydrates of alkylated diamines are difficultly soluble in water.

The compounds thus obtained, with the exception of compounds 4 and 5 (see table), were purified by recrystallization from water with aqueous solutions of hydrochloric acid. Compounds 4 and 5 were purified by reprecipitation from methyl alcohol with a small amount of hydrochloric acid. After recrystallization, Compounds 6, 7, 8, and 10 were washed with ether, and compound 9 with acetone.

SUMMARY

The properties and methods of synthesis of some 4,4'-diamidines of stilbene and some 2-substituted stilbenes have been described.

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* In the production of methylated diamidines, the methylamine solution was prepared in the following manner: the theoretically calculated amount of metallic sodium was added to excess ethyl alcohol, then the hydrochloride of methyl amine was gradually added to the obtained alcoholic solution at room temperature (a 30 % excess of methylamine hydrochloride as compared to the theoretically calculated amount was used).

THE SYNTHESIS OF HALOGENATED DERIVATIVES OF PHENAZINE

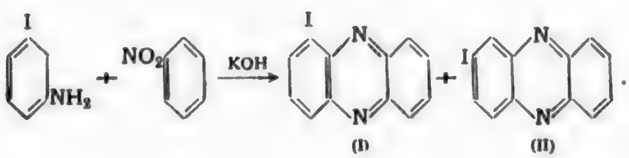
V. IODOPHENAZINES

V. P. Chernetsky and A. I. Kiprianov

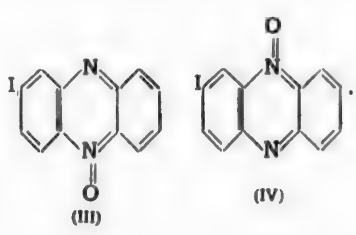
In previous papers we described the synthesis of fluoro-, chloro- and bromophenazines mainly by alkaline condensation of halonitrobenzenes with aniline or of nitrobenzene with haloanilines [1]. In the present communication we report the results of similar experiments aimed at the preparation of iodophenazines.

Three iodo derivatives of phenazine were previously known: 2,6-diiodophenazine and its N-oxide [2] and the recently described 2-iodophenazine [3]. 1-Iodophenazine had never been prepared.

It might have been expected that both isomeric iodophenazines would be formed by alkaline condensation of m-iodoaniline with nitrobenzene:



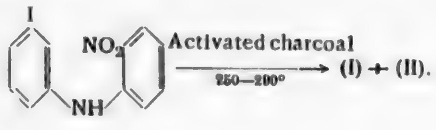
On carrying out this condensation, however, we only isolated 2-iodophenazine (II) in small quantity and the N-oxide of iodophenazine which on reduction was converted into 2-iodophenazine. Since the NO group is formed at the expense of the NO_2 group, the oxide that we obtained must be regarded as the 10-oxide of 2-iodophenazine (III). Neither 1-iodophenazine nor its N-oxide was detected in the reaction products. Their formation is evidently prevented by steric hindrance.



By condensing p-iodoaniline with nitrobenzene we obtained a little 2-iodophenazine (II) and its 9-oxide (IV). A mixed sample of 9- and 10-oxides of 2-iodophenazine showed a considerable depression of melting

point. Reduction of both oxides gave one and the same 2-iodophenazine.

Chromatogramming of the products of condensation of m-iodoaniline with nitrobenzene on alumina yielded 3-iodo-2'-nitrodiphenylamine. Heating of the latter with activated charcoal gave 1- and 2-iodophenazines:



The iodophenazines that we synthesized are listed in Table 1.

TABLE 1

Compound	Melting point
1-Iodophenazine (I)	142-143°
2-Iodophenazine (II)	170-171, 169.5-170 [3]
10-Oxide of 2-iodophenazine (III)	190-191, decomp. at 204-205
9-Oxide of 2-iodophenazine (IV)	167-168, decomp. at 204-206

Chromatogramming of the products of the above condensation reactions that were soluble in organic solvents led to separation of a series of iodoazo- and iodoazoxybenzenes and iodonitrodiphenylamines. Their structures were confirmed by analytical data, by their distribution in the chromatographic column, by the color of the crystals and by qualitative reactions. Data for these products are presented in Table 2.

EXPERIMENTAL

The procedure for alkaline condensation in organic solvents has been described previously [1]. Since the N-oxides of iodophenazines, like the N-oxides of bromophenazines, form sparingly soluble salts with hydrochloric acid, they were likewise separated in the form of these salts.

Condensation of m-iodoaniline with nitrobenzene. 21.9 g m-iodoaniline, 12.3 g nitrobenzene and 35 g potassium hydroxide powder were boiled in 150 ml benzene for $2\frac{1}{2}$ hours. 18 mg (0.06%) 2-iodophenazine was separated: pale-yellow needles from methyl alcohol; a mixture with pure 2-iodophenazine, obtained by condensation of p-iodoaniline with nitrobenzene, melted without depression. In addition 0.74 g (2.3%) of the 10-oxide of 2-iodophenazine was isolated: bright-yellow needles from ligroine-benzene mixture.

Found %: N 8.70, 8.52; I 39.28, 39.50. $C_{12}H_7ON_2I$. Calculated %: N 8.69; I 39.44.

The following other products were obtained: 3-iodoazobenzene (9.9%), 3-iodoazoxybenzene (1.4%), 3-iodo-2'-nitrodiphenylamine (11.4%), and 3-iodo-4'-nitrodiphenylamine (1.4%).

Condensation of p-iodoaniline with nitrobenzene. 21.9 g p-iodoaniline, 12.3 g nitrobenzene and 35 g potassium hydroxide powder were boiled in 150 ml benzene for 4 hours. 157 mg (0.51%) 2-iodophenazine and 0.74 g (2.3%) 9-oxide of 2-iodophenazine were isolated: bright-yellow, flat needles from a mixture of ligroine and benzene.

Analysis of 2-iodophenazine. Found %: N 9.06, 9.00; I 41.80. $C_{12}H_7N_2I$. Calculated %: N 9.15; I 41.50.

Analysis of oxide: Found %: N 8.46, 8.60; I 39.53, 39.41. $C_{12}H_7ON_2I$. Calculated %: N 8.69; I 39.44.

The following were also isolated: 4-iodoazobenzene (16%), 4-iodoazoxybenzene (0.9%), 4-iodo-2'-nitrodiphenylamine (3.8%), 4-iodo-4'-nitrodiphenylamine (3.5%).

Cyclization of 3-iodo-2'-nitrodiphenylamine. 3.5 g 3-iodo-2'-nitrodiphenylamine was thoroughly mixed with 7 g of activated charcoal and heated at 250-290° for 15 minutes. The mixture was extracted with benzene

TABLE 2

Formula	Appearance of crystals	Solvent for crystallization	Melting point	Results of analysis: found (%) N	found (%) I	composition	calculated (%) N	calculated (%) I
m-$IC_6H_4-N=N-C_6H_5$	Orange needles	Alcohol	72—73°	9.16, 9.20	41.50, 41.42	$C_{12}H_9N_2I$	9.09	41.23
m-$IC_6H_4-N=\underset{\substack{\vert\\ O}}{N}-C_6H_5$	Yellow needles	Alcohol	75—76	8.76, 8.80	39.41, 39.45	$C_{12}H_9ON_2I$	8.63	39.20
p-$IC_6H_4-N=N-C_6H_5$	Orange leaflets	Ligroine	108—109 [4]	9.10, 8.82	41.44, 41.15	$C_{12}H_9N_2I$	9.09	41.23
p-$IC_6H_4-N=\underset{\substack{\vert\\ O}}{N}-C_6H_5$	Yellowish leaflets	Methyl alcohol	88—89	8.62, 8.55	39.34, 39.18	$C_{12}H_9ON_2I$	8.63	39.20
m-$IC_6H_4NHC_6H_4NO_2$-(o)	Orange-red needles	Methyl alc. + benzene	88—89	8.49, 8.28	37.50, 37.41	$C_{12}H_9O_2N_2I$	8.23	37.35
m-$IC_6H_4NHC_6H_4NO_2$-(p)	Yellow-brown needles	Benzene	153—154	8.33, 8.33	36.97, 37.11	$C_{12}H_9O_2N_2I$	8.23	37.35
p-$IC_6H_4NHC_6H_4NO_2$-(o)	Orange-red needles	Alcohol + benzene	171—172	8.36, 8.37	37.60, 37.42	$C_{12}H_9O_2N_2I$	8.23	37.35
p-$IC_6H_4NHC_6H_4NO_2$-(p)	Orange-yellow needles	Benzene + ligroine	148—149	8.10, 8.18	37.22, 37.09	$C_{12}H_9O_2N_2I$	8.23	37.35

in a hot-extraction apparatus and chromatogrammed on alumina. 0.22 g 1-iodophenazine (yellow needles from methyl alcohol) and 0.36 g 2-iodophenazine were separated. In a mixed test with 2-iodophenazine prepared by alkaline condensation the second compound did not give a depression of m.p.

Analysis of 1-iodophenazine. Found %: N 9.02, 9.20; I 41.20, 41.31. $C_{12}H_7N_2I$. Calculated %: N 9.15; I 41.50.

SUMMARY

Alkaline condensation of iodoanilines with nitrobenzene gave 2-iodophenazine and the 9- and 10-oxides of 2-iodophenazine in addition to a number of secondary and intermediate products: 3- and 4-iodoazobenzenes, 3- and 4-iodoazoxybenzenes, 3-iodo-2'- and 3-iodo-4'-nitrodiphenylamines, and 4-iodo-2'- and 4-iodo-4'-nitrodiphenylamines.

Heating of 3-iodo-2'-nitrodiphenylamine with activated charcoal gave 1- and 2-iodophenazines.

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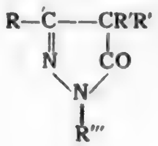
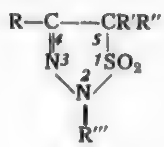
SYNTHESIS OF DERIVATIVES OF 1,2,3-THIADIAZOLINES

A. P. Terentyev and M. N. Preobrazhenskaya

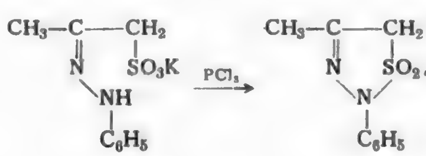
The great practical and theoretical importance of pyrazolone derivatives has attracted and continues to attract the attention of investigators. It was considered of interest to study the properties of substances in which the SO_2 group takes the place of the carbonyl group of pyrazolones (I).

These compounds of the general formula (II) were named 1,1-dioxides of 1,2,3-thiadiazolines by us.*


(I)


(II)

Only one representative of this class of compounds has been described [1]; it was obtained by cyclization of the phenylhydrazone of the potassium salt of acetone sulfonic acid with the help of phosphorus trichloride:



Due, however, to the difficult accessibility of the β-ketosulfonic acids, this reaction was not further applied. The properties of the 1,1-dioxides of 1,2,3-thiadiazolines remained little studied. The method of sulfonation of ketones with the help of dioxane sulfotrioxide, developed in 1950 by A. P. Terentyev and L. A. Yanovskaya [2], made the β-ketosulfonic acids easily accessible. The method gives high yields of β-ketosulfonic acids (84-90%).

By sulfonation of ketones with dioxane sulfotrioxide we obtained salts of the following β-ketosulfonic acids: $CH_3COCH_2SO_3H$ (acetonesulfonic acid), $CH_3CO\underset{\displaystyle CH_3}{\underset{|}{C}}HSO_3H$ (methylethyl ketone sulfonic acid),

* The numbering of the atoms in this ring commences, as usual for monocyclic azoles, with the heteroatom located in the highest group of Mendeleev's table, i.e. with sulfur, and goes by the shortest route in the direction of the nitrogen.

$CH_3COCHSO_3H$ (methylisobutyl ketone sulfonic acid) and $p\text{-}CH_3C_6H_4COCH_2SO_3H$ (ω-sulfonic acid of p-tolyl-

$\quad\quad | $

$\quad\quad CH(CH_3)_2$

methyl ketone).

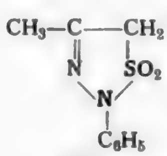
We avoided the formation of disulfonic acids of the ketones by taking a slight excess of ketone in relation to dioxane sulfotrixoide.

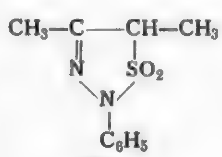
Phenylhydrazones of the salts of β-ketosulfonic acids were synthesized by heating aqueous saturated solutions of equivalent amounts of the salt of the β-ketosulfonic acid and phenylhydrazine (or salt of β-ketosulfonic acid, phenylhydrazine hydrochloride and potassium acetate). Syntheses were effected of the phenylhydrazones of salts of acetone sulfonic acid, methylethyl ketone sulfonic acid, methylisobutyl ketone sulfonic acid and the ω-sulfonic acid of methyl-p-tolyl ketone. The relatively low yields (60-80%) may have been due to the solubility in water of the compounds formed and of the starting salts of the sulfoketones. Thus, the phenylhydrazone of the barium salt (the least soluble in water) of acetone sulfonic acid was obtained in 85% yield, while the phenylhydrazone of the more water-soluble sodium salt was obtained in 74% yield. Replacement of free phenylhydrazine by the hydrochloride does not affect the yield. In some experiments with salts of methylisobutyl ketone sulfonic acid, so much resinous secondary product was formed that the phenylhydrazone could not always be isolated in crystalline form.

Mention has been made in the literature [3] of the difficulty and even impossibility of obtaining such derivatives of β-ketosulfonic acids as semicarbazones and oximes. We succeeded, however, in isolating the oxime, semicarbazone, acetylhydrazone and p-nitrophenylhydrazone of salts of acetone sulfonic acid. These derivatives are difficult to isolate because they are readily soluble in water (an exception is the p-nitrophenylhydrazone).

1,1-Dioxides of 1,2,3-thiadiazolines were prepared by the action of phosphorus trichloride on the phenylhydrazones of the potassium salts of β-ketosulfonic acids. It is interesting to note that the phenylhydrazones of the sodium and barium salts of acetone sulfonic acid do not react with phosphorus trichloride.

The following were prepared: the 1,1-dioxide of 2-phenyl-4-methyl-1,2,3-thiadiazoline (III); the 1,1-dioxide of 2-phenyl-4,5-diethyl-1,2,3 thiadiazoline (IV) and the 1,1-dioxide of 2-phenyl-4-methyl-5-isopropyl-1,2,3-thiadiazoline (V).


(III)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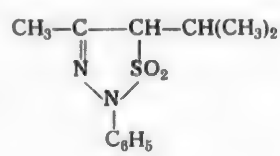
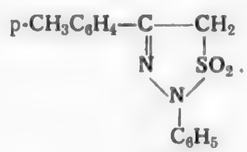
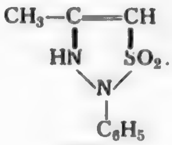

(V)

A striking exception is the phenylhydrazone of the barium salt of methyl-p-tolyl ketone sulfonic acid which forms the 1,1-dioxide of 2-phenyl-4-(p-tolyl)-1,2,3-thiadiazoline (VI).


(VI)

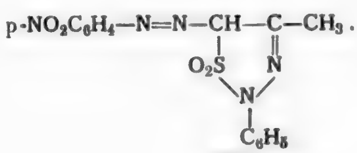
The cyclization reaction is accompanied by formation of secondary colored substances, as well as of compounds with a very unpleasant odor reminiscent of skatole (especially when the phenylhydrazone contains a trace of moisture).

The chemical properties of 1,1-dioxides of 1,2,3-thiadiazolines are typified by the properties of compound (III). The latter does not form a picrate, does not give a salt with hydrogen chloride, is not methylated by methyl iodide or dimethyl sulfate (the methods developed for pyrazolones were applied), does not undergo Schotten-Baumann benzoylation and is not acetylated on heating with acetic anhydride. Consequently, unlike the pyrazolones, the 1,1-dioxide of thiadiazoline does not form derivatives of the tautomeric form (VII).



(VII)

Regarding the methylene group, its reactivity in a thiadiazoline dioxide is much lower than in pyrazolones. Nitrosation with sodium nitrite in a medium of acetic acid or with isoamyl nitrite in presence of traces of hydrochloric acid did not lead to formation of nitroso compounds; the substance was recovered unchanged. Phenyldiazonium chloride does not undergo azo-coupling with 2-phenyl-4-methyl-1,2,3-thiadiazoline 1,1-dioxide in potassium acetate solution, but a stronger reagent (p-nitrophenyldiazonium chloride) gave an azo dye whose structure may be represented by (VIII).



(VIII)

2-Phenyl-4-methyl-1,2,3-thiadiazoline 1,1-dioxide (III) possesses bacteriostatic activity against acid-resistant organisms, in particular the bacillus of human tuberculosis. The preparation is active in vitro in a dilution of 1:2,048,000; it is less active against avian tuberculosis (1:64,000). The phenylhydrazone of the potassium salt of acetone sulfonic acid is active against the bacillus of human tuberculosis in a dilution of 1:256,000. In presence of 10% serum the preparations are inactive.

The potassium salt of acetone sulfonic acid and the oxime of the ammonium salt of this acid are lacking in interest as antimicrobial agents.

Our preparations were investigated for bacteriostatic action in the department of chemotherapy of the All-Union S. Ordzhonikidze Institute of Pharmaceutical Chemical Research under the direction of G. N. Pershin. It is our pleasant duty to express our gratitude to him.

EXPERIMENTAL

I. Preparation of β-ketosulfonic Acids

1. Acetone sulfonic acid. To a solution of acetone (58 g) in dichloroethane (50 ml), cooled to below 0°, was added a suspension of dioxane sulfotrioxide in dichloroethane (prepared from 40 g sulfur trioxide and 54 g dioxane in 150 ml dichloroethane), the temperature not being allowed to rise above +10°. The reaction mixture was stood overnight at room temperature and the resultant solution was neutralized with a suspension of

barium carbonate in water (200 g). The hot solution was filtered from sulfate and excess barium carbonate and evaporated to dryness on a water bath. The barium acetone sulfonate was dried in vacuum at 100°. The yield of barium salt was 98 g, equal to 95.5% on the basis of the sulfur trioxide. The substance is readily soluble in water and insoluble in organic solvents. For the purpose of analysis it was twice recrystallized from aqueous ethyl alcohol and dried in vacuum at 110°.

Found %: Ba 33.2, 33.4. $C_6H_{10}O_8S_2Ba$. Calculated %: Ba 33.2.

Sodium acetone sulfonate was prepared from the barium salt by treatment of its aqueous solution with sodium sulfate; after removal of the barium sulfate, the mother liquor was evaporated and the sodium salt of the sulfonic acid extracted with anhydrous ethyl alcohol.

Phenylhydrazones of salts of acetone sulfonic acid. 41.2 g barium acetone sulfonate in 90 ml water was mixed with a solution of 21.6 g freshly distilled phenylhydrazine in 55 ml 50% acetic acid. A precipitate appeared almost at once and 50.7 g of the phenylhydrazone of barium acetone sulfonate was obtained. Yield 86%. For the purpose of analysis the substance was twice recrystallized from aqueous ethanol.

Found %: Ba 23.26, 23.26. $C_{18}H_{22}N_4O_6S_2Ba$. Calculated %: Ba 23.21.

With the help of phenylhydrazine hydrochloride, the phenylhydrazone of the barium salt was obtained in 85%, potassium salt 70% and sodium salt 74% yield. The compounds are soluble in water. The phenylhydrazones of the salts of β-ketosulfonic acids were brought into reactions without previous recrystallization.

Oximes of salts of acetone sulfonic acid. A solution of 50 g barium acetone sulfonate was mixed with a solution of 23 g of potassium sulfate, the barium sulfate was filtered off, the mother liquor was evaporated down until crystallization commenced and a concentrated solution of 17 g hydroxylamine hydrochloride was added. To the reaction mixture was added 17 g potassium carbonate. The solution was heated to the boil for half an hour. After cooling, 11.6 g substance was obtained and evaporation of the mother liquor gave a further 9 g. Yield 45%. For analysis, the substance was twice recrystallized from aqueous ethanol.

Found %: C 18.84, 18.85; H 3.42; 3.23; K 20.72, 20.61. $C_3H_6NO_4SK$. Calculated %: C 18.84; H 3.16; K 20.44.

The oxime of barium acetone sulfonate was obtained in 84% yield and that of ammonium acetone sulfonate in 72% yield.

Semicarbazone of potassium acetone sulfonate. To a concentrated solution of potassium acetone sulfonate, prepared from 50 g barium acetone sulfonate, and 21.1 g potassium sulfate, was added a saturated solution of 27 g semicarbazide hydrochloride and 25 g potassium acetate. The reaction mixture was stood overnight. After removal of the precipitate and evaporation of the mother liquor, 40 g semicarbazone of potassium acetone sulfonate was obtained in the form of snow-white crystals. The salt crystallizes with one molecule of water. Yield 66.6%. For the purpose of analysis it was recrystallized from water and dried in a vacuum-desiccator over calcium chloride.

Found %: C 19.41, 19.49; H 4.19, 4.20; K 15.98, 15.04. $C_4H_8N_3O_4SK \cdot H_2O$. Calculated %: C 19.21; H 4.04; K 15.55.

Acetylhydrazone of sodium acetone sulfonate. 6 g of sodium acetone sulfonate was dissolved with heating in the minimum amount of ethyl alcohol and run into a hot concentrated solution of 3 g acetylhydrazine in ethyl alcohol. Crystallization commenced after 3 hours and 5 g of colorless crystals was obtained. Yield 65.5%. For analysis the substance was twice recrystallized from 80% ethyl alcohol and dried in a vacuum-desiccator over calcium chloride. The compound crystallizes with one molecule of water. The acetylhydrazone of sodium acetone sulfonate is easily soluble in water and in methanol, poorly soluble in ethyl alcohol, and insoluble in dioxane, benzene and chloroform.

Found %: N 12.01, 12.21. $C_5H_9NO_4SNa \cdot H_2O$. Calculated %: N 11.96.

p-Nitrophenylhydrazone of potassium acetone sulfonate. 7 g potassium acetone sulfonate was dissolved in the minimum amount of water and run into a hot solution of 6.6 g p-nitrophenylhydrazine in 100 ml 70%

ethyl alcohol; a few drops of glacial acetic acid were added to the reaction mixture. 12.4 g of the p-nitrophenylhydrazone of potassium acetone sulfonate was obtained. Bright-yellow crystals. Poorly soluble in water. The yield was quantitative.

2. Methylethyl ketone sulfonic acid. Dioxane sulfotrioxide was prepared from 48 g sulfur trioxide and 88 g dioxane in 200 ml dichloroethane. The sulfonating agent was added with stirring and cooling to 50 g methylethyl ketone. Suitable working up led to isolation of 75 g barium methylethyl ketone sulfonate. The substance was dried in vacuum at 100°. Yield 59.7%. For analysis, the barium salt was twice recrystallized from moist dioxane and dried in vacuum at 110°. The compound is very soluble in water and insoluble in common organic solvents. Analysis reveals the presence of water of crystallization.

Found %: Ba 28.87, 28.69. $C_8H_{14}O_8S_2Ba \cdot 2H_2O$. Calculated %: Ba 28.89.

Phenylhydrazone of potassium methylethyl ketone sulfonate. The reaction mixture was prepared from hot saturated solutions of 22 g barium salt of the sulfonic acid, 9 g potassium sulfate, 14.4 g phenylhydrazine hydrochloride and 10 g potassium acetate. The compound began to crystallize a few minutes after completion of 3 hours heating. Yield 14 g light-yellow crystals. Evaporation of the mother liquor yielded another 8.5 g. The yield was equivalent to 72%. The compound is readily soluble in water and aqueous alcohol.

3. Methylisobutyl ketone sulfonic acid. 70 g methylisobutyl ketone was sulfonated with a suspension of dioxane sulfotrioxide in dichloroethane prepared from 40 g sulfur trioxide and 75 g dioxane. Treatment with barium carbonate gave 122 g of barium methylisobutyl ketone sulfonate (the salt was dried in vacuum at 110°). It is very soluble in water and insoluble in organic solvents.

Found %: C 28.94, 28.91; H 4.62, 4.66; Ba 27.72, 27.75. $C_{12}H_{22}S_2O_8Ba$. Calculated %: C 29.13; H 4.77; Ba 27.71.

Phenylhydrazone of potassium methylisobutyl ketone sulfonate. From 17 g barium methylisobutyl ketone sulfonate and 11 g potassium sulfate was obtained a solution of the potassium salt of the sulfonic acid. The solution was evaporated until crystallization commenced, saturated solutions of 9.5 g phenylhydrazine hydrochloride and 6 g potassium acetate were added, and the reaction mixture was heated at the boil for 3 hours. A dark-green oil separated out. The reaction mixture was allowed to stand overnight. The contents of the flask set to a paste which was pressed on porous plate. Colorless crystals were thus obtained and were dried in vacuum at 80°; yield 16.1 g (80%) of the phenylhydrazone of potassium methylisobutyl ketone sulfonate. Readily soluble in water and in aqueous alcohol.

4. ω-Sulfonic acid of p-tolylmethyl ketone. 81 g p-tolylmethyl ketone was sulfonated with a suspension of dioxane sulfotrioxide in 150 ml dichloroethane. The dioxane sulfotrioxide was prepared from 40 g sulfur trioxide and 88 g dioxane. 45 g of the barium salt of the sulfonic acid was obtained. Yield 32%. The salt is poorly soluble in water. For the purpose of analysis the substance was twice recrystallized from water, dried by distillation of the water with benzene and then in a vacuum-desiccator over paraffin wax and calcium chloride.

Found %: C 38.27, 38.42; H 3.47, 3.41. $C_{19}H_{18}S_2O_8Ba$. Calculated %: C 38.34; H 3.22.

Phenylhydrazone of barium p-tolylmethyl ketone sulfonate. 20 g of barium methyl-p-tolyl ketone sulfonate was dissolved with heating in 200 ml water, and a solution of 7.8 g phenylhydrazine in 50 ml 50% acetic acid was added. Crystals began to separate out with continued heating of the reaction mixture. Yield 20 g (77%). Poorly soluble in water and organic solvents.

II. Preparation of 1,1-dioxides of 1,2,3-thiadiazolines.

1,1-Dioxide of 2-phenyl-4-methyl-1,2,3-thiadiazoline (III). 40 g phenylhydrazone of potassium acetone sulfonic acid, carefully dried in vacuum at 100°, was cautiously added to 80 ml phosphorus trichloride. The reaction mixture was heated on a water bath for 1 hour and then poured onto ice. The 1,1-dioxide of the thiadiazoline was obtained in the form of an amorphous precipitate. Yield 15.5 g (62%). The compound crystallized from aqueous alcohol, aqueous acetic acid and ligroine in the form of pale-yellow needles. Insoluble in water. M.p. 85.5-86°.

Found %: C 51.63, 51.78; H 4.89, 4.84. $C_9H_{10}N_2O_2S$. Calculated %: C 51.42; H 4.79.

1,1-Dioxide of 2-phenyl-4,5-dimethyl-1,2,3-thiadiazoline (IV). The 1,1-dioxide of the thiadiazoline was prepared by reaction of 9 g phenylhydrazone of potassium methylethyl ketone sulfonate with 15 ml phosphorus trichloride. After pouring the reaction mixture onto ice, a yellowish-green amorphous precipitate was obtained. Yield 4.5 g (62.4%). The compound was purified by reprecipitation with water from ethyl alcohol and was then recrystallized from aqueous ethyl alcohol. M.p. 83-83.5°. Insoluble in water and ligroine, soluble in the usual organic solvents.

Found %: C 53.45, 53.52; H 5.36, 5.41. $C_{10}H_{12}N_2O_2S$. Calculated %: C 53.57; H 5.40.

1,1-Dioxide of 2-phenyl-4-methyl-5-isopropyl-1,2,3-thiadiazoline (V). 3 g of the 1,1-dioxide of the thiadiazoline was prepared by treating 10.3 g of the phenylhydrazone of the potassium salt of methylisobutyl ketonesulfonic acid with 15 ml of phosphorus trichloride. An oil formed when the reaction mixture was poured onto ice and it crystallized in the course of a few minutes. Yield 37%. The unpurified substance has a very unpleasant odor reminiscent of skatole. It crystallizes from aqueous ethyl alcohol and aqueous acetic acid. It was purified by dissolving in ethyl alcohol and precipitation with water; the substance was then recrystallized from aqueous ethyl alcohol. M.p. 59.5-60°.

Found %: C 57.01, 57.12; H 6.61, 6.41. $C_{12}H_{16}N_2O_2S$. Calculated %: C 57.12; H 6.39.

1,1-Dioxide of 2-phenyl-4-(p-tolyl)-1,2,3-thiadiazoline (VI). The thiadiazoline dioxide was obtained by reacting 3.7 g phenylhydrazone of barium methyl-p-tolyl ketone ω-sulfonate with 15 ml phosphorus trichloride. Yield 80%. The compound dissolves easily in acetone, dioxane, chloroform and glacial acetic acid; it is rather less soluble in ether and carbon tetrachloride; it is insoluble in water and dissolves in ethyl alcohol on heating. Recrystallization from ethyl alcohol gave a substance with m.p. 155-156° (with decomp.). It turns appreciably yellow at 145°.

Found %: N 9.84, 9.75. $C_{15}H_{14}N_2O_2S$. Calculated %: N 9.79.

III. Some Reactions of 1,1-dioxides of Thiadiazolines.

1. Azo coupling of p-nitrophenyldiazonium chloride with 2-phenyl-4-methyl-1,2,3-thiadiazoline 1,1-dioxide. To a solution of 4 g of the thiadiazoline 1,1-dioxide and 20 g potassium acetate in 70 ml methyl alcohol was added dropwise, with stirring and with cooling to -5°, a solution of p-nitrophenyldiazonium chloride prepared from 2.1 g p-nitroaniline and 1.5 g sodium nitrite. After the diazo solution had been run in, stirring was continued for 2 hours. The dark-red precipitate was suction-filtered, washed with water and cold methanol, and dried in a vacuum-desiccator. 6 g substance was obtained, readily soluble in acetone, poorly soluble in the cold in benzene and alcohol, insoluble in water and isooctane. The presumed product of azocoupling was purified by precipitation from acetone with isooctane. Dark-red crystals of (VIII) were obtained. Depending upon the rate of heating, the melting point was between 130 and 135°.

Found %: N 18.70, 18.50. $C_{15}H_{13}O_4N_5S$. Calculated %: N 19.48.

2. Nitrosation of 2-phenyl-4-methyl-1,2,3-thiadiazoline 1,1-dioxide. To a solution of 1.7 g thiadiazoline dioxide in 50 ml 70% acetic acid was added dropwise a solution of 1 g sodium nitrite in water. The reaction mixture was left overnight. Dilution with water led to precipitation of crystals (1 g) which after recrystallization from aqueous ethyl alcohol had m.p. 84-84.5°. No depression of melting point was observed in a test in admixture with the original thiadiazoline dioxide.

Heating to the boil of the thiadiazoline dioxide with isoamyl nitrite in presence of traces of hydrochloric acid for 20 hours led to complete resinification of the reaction mixture; after 10 hours heating the starting substance was isolated in 80% yield.

3. Methylation of 2-phenyl-4-methyl-1,2,3-thiadiazoline 1,1-dioxide with methyl iodide. 3 g of the thiadiazoline dioxide, 2.4 g methyl iodide and 5 ml methyl alcohol were heated in a sealed tube to 100° for 4 hours and the mixture was then left overnight before pouring into water. The crystals were recrystallized from aqueous methyl alcohol. Yield 1.5 g with m.p. 80° (no depression with pure thiadiazoline 1,1-dioxide). When the aqueous alcoholic mother liquor was made alkaline, traces of a substance separated out. This had

a pungent, unpleasant odor and formed an ash when burned. It was evidently a product of decomposition of the thiadiazoline dioxide.

4. Methylation of 2-phenyl-4-methyl-1,2,3-thiadiazoline 1,1-dioxide with dimethyl sulfate. 3 g of the thiadiazoline dioxide was dissolved in benzene; dropwise addition was made to this solution, with vigorous stirring and heating, of 9 g freshly distilled dimethyl sulfate. The reaction mixture was afterwards heated for 5 hours. Water was added, the benzene layer was separated, the aqueous layer was washed with ether and the ether layer was added to the benzene layer. The benzene-ether mixture was dried with anhydrous sodium sulfate and the solvents taken off in vacuum. 2 g of badly resinified starting substance was obtained. The aqueous layer was made alkaline and subjected to extraction with ether. Traces of a substance with an unpleasant odor were obtained after drying with potassium carbonate and removing the solvent.

SUMMARY

1. Some chemical properties of β-ketosulfonic acids were studied. Characteristic derivatives of β-ketosulfonic acids were prepared.

2. New compounds in the series of 1,1-dioxides of 1,2,3-thiadiazolines, which are structural analogs of pyrazolones, were synthesized: 1,1-dioxide of 2-phenyl-4,5-dimethyl-1,2,3-thiadiazoline; 1,1-dioxide of 2-phenyl-4-methyl-5-isopropyl-1,2,3-thiadiazoline; 1,1-dioxide of 2-phenyl-4-(p-tolyl)-1,2,3-thiadiazoline.

3. These compounds differ markedly in chemical properties from the 5-pyrazolones.

4. The 1,1-dioxide of 2-phenyl-4-methyl-1,2,3-thiadiazoline is found to be active in vitro against acid-resistant bacteria.

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ALKAMINE ESTERS OF α,β-DIPHENYLPROPIONIC ACID

II. DERIVATIVES OF β-(4-METHOXYPHENYL)-α-PHENYLPROPIONIC ACID

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In the preceding communication [1] we described a series of alkamine esters of β-(4-hydroxyphenyl)- and β-(4-acetoxyphenyl)-α-phenylpropionic acid. These esters possessed considerable spasmolytic activity. Considerable difficulties were encountered in the synthesis of these compounds via the acid chlorides due to the presence of the 4-hydroxyphenyl residue in the molecule: after treatment of β-(4-hydroxyphenyl)-α-phenylpropionic acid with agents promoting the formation of acid chlorides ($SOCl_2$, PCl_5, etc.), the chloride of this acid could not be isolated in the pure state. For the synthesis of alkamine esters we therefore applied the method of transesterification of the ethyl ester of β-(hydroxyphenyl)-α-phenylpropionic acid in presence of a small amount of sodium alkoxide; alternatively we protected the hydroxy group with acylating residues. In the preparation of β-(4-hydroxyphenyl)-α-phenylpropionic acid, the penultimate step of the synthesis is the formation of β-(4-methoxy)-α-phenylpropionic acid which gives the normal, pure acid chloride from which the alkamine esters can be obtained in good yields. On the basis of the observation that in the human organism p-methoxyphenyl compounds often manifest biological properties of the same type as their corresponding p-hydroxy compounds (sometimes in intensified form [2]), it may be suggested that this is the result of dealkylation of secondary compounds in the organism. We therefore decided to study a series of derivatives of β-(4-methoxyphenyl)-α-phenylpropionic acid, starting with the most interesting compounds—the alkamine esters. Our objective was to establish to what extent the biological properties were altered by replacement of the OH group by the CH_3O group. Starting from β-(methoxyphenyl)-α-phenylpropionyl chloride, we prepared the following: the 2-N,N-diethylaminoethyl, 3,N,N-dimethylaminopropyl and the tropyl esters; also the amide, hydrazide, 2-N,N-diethylaminoethylamide, 3-N,N-diethylamino-2-hydroxypropylamide and 4-N,N-diethylaminobutylamide. Our hypothesis of the activity of the methoxy compounds was confirmed in biological tests on these compounds carried out by M. D. Mashkovsky and K. A. Zaitsev [3]. The latter also observed that whereas the alkamine esters possess considerable spasmolytic activity, the tropyl ester has a more strongly developed adrenolytic effect. For comparison of the role of the methoxy group with that of the acetoxy group, we also synthesized the 4-acetoxy compound; the biological action of the latter was nearly the same as that of the methoxy compound.

EXPERIMENTAL

β-(4-Methoxyphenyl)-α-phenylpropionic acid. 300 g β-(4-methoxyphenyl)-α-phenylacrylic acid, 1500 ml water, 60 g sodium hydroxide and 30 g skeletal nickel were charged into a three-liter rotating autoclave. The autoclave was then charged with hydrogen to a pressure of 60 atm. Hydrogenation was completed in 4 hours at 90-100° [1]. The autoclave was cooled and the solution was filtered from catalyst and acidified with hydrochloric acid (congo test). The crystalline acid was filtered off, washed with water and dried. M.p. 119-121°. Yield 317 g (97.5%).

Literature data [4]: m.p. 120-121°.

Ethyl β-(4-methoxyphenyl)-α-phenylpropionate. A mixture of 5 g β-(4-methoxyphenyl)-α-phenylpropionic acid, 12 ml anhydrous alcohol and 2.5 ml concentrated sulfuric acid was refluxed on a water bath for

5 hours. At the end of the reaction the oil was poured into water. The resultant precipitate was filtered, washed with water, then with 5% sodium carbonate and again with water. Recrystallization from alcohol gave 5.2 g (94.5%) with m.p. 56-57°. White crystals, soluble in alcohol, ether and benzene.

Found %: C 75.83, 76.26; H 7.17, 7.02. $C_{18}H_{20}O_3$. Calculated %: C 76.01; H 7.02.

β-(4-Methoxyphenyl)-α-phenylpropionyl chloride. 15 g β-(4-methoxyphenyl)-α-phenylpropionic acid and 9 g thionyl chloride were stirred and heated for 2 hours at 70° until the acid had completely dissolved. At the end of the reaction the excess of thionyl chloride was distilled off in vacuum. The residue was recrystallized from 12.5 ml gasoline. White crystals with m.p. 63-65°. Yield 14.1 g (90%). Soluble in benzene, ether and gasoline; decomposes in water.

Found %: C 70.01; H 5.56; Cl 12.72. $C_{16}H_{15}O_2Cl$. Calculated %: C 69.94; H 5.46; Cl 12.91.

β-(4-Methoxyphenyl)-α-phenylpropionamide. A mixture of 5 g β-(4-methoxyphenyl)-α-phenylpropionyl chloride and 25 ml 20% solution of ammonia in methyl alcohol was stood for 48 hours. The precipitate was filtered and recrystallized from alcohol. White needles with m.p. 158-159°. Soluble in hot water and alcohol; insoluble in cold water and cold alcohol.

Found %: C 75.46, 75.09; H 6.99, 6.73; N 5.12. $C_{16}H_{17}O_2N$. Calculated %: C 75.25; H 6.81; N 5.49.

Hydrazide of β-(4-methoxyphenyl)-α-phenylpropionic acid. 2 g ethyl β-(4-methoxyphenyl)-α-phenylpropionate, 10 ml anhydrous alcohol and 3 ml hydrazine hydrate were heated for 3 hours at 120°. The alcohol was then driven off. The residue was recrystallized from water to give 1.7 g (93%), m.p. 129-130°.

Found %: C 70.99; H 6.63. $C_{15}H_{18}O_2N_2$. Calculated %: C 71.07; H 6.74.

2-N,N-Diethylaminoethyl ester of β-(4-methoxyphenyl)-α-phenylpropionic acid. A mixture of 5 g β-(4-methoxyphenyl)-α-phenylpropionyl chloride, 10 g dry benzene and 8 g diethylaminoethanol was refluxed and stirred for 4 hours. The alcohol was then taken off in vacuum together with unreacted diethylaminoethanol. The residue was dissolved in water, made alkaline with sodium carbonate solution and extracted with ether. After drying, the ether was driven off. The residue was distilled at 160-163° (1 mm) to give 5 g (84.5%) of a yellow, viscous oil. Soluble in alcohol and hydrochloric acid; insoluble in water.

Found %: N 3.77. $C_{22}H_{29}O_3N$. Calculated %: N 3.94.

The theoretical amount of hydrogen chloride in anhydrous alcohol was added to a solution of the base in anhydrous alcohol. The resultant white crystals were filtered. Yield 4.5 g (82%) of hydrochloride with m.p. 110-112°. Readily soluble in water; insoluble in anhydrous alcohol and ether.

Found %: N 3.69, 3.58; Cl 9.23. $C_{22}H_{29}O_3N \cdot HCl$. Calculated %: N 3.57; Cl 9.05.

3-N,N-Dimethylaminopropyl ester of β-(4-methoxyphenyl)-α-phenylpropionic acid. 3 g β-(4-methoxyphenyl)-α-phenylpropionic acid was dissolved with heating in a solution of sodium ethoxide (from 15 ml ethyl alcohol and 0.27 g metallic sodium). The solution was evaporated to dryness in vacuum. To the dry residue was added 3 g 2-N,N-dimethylaminopropyl chloride in 20 ml dry benzene. The mixture was stirred and boiled for 3 hours. The precipitated sodium chloride was then filtered off and washed with dry benzene. The benzene was removed in vacuum and then the residual base was distilled at 175-178° (1-1.5 mm) in the form of a viscous, yellow oil. Yield 2.6 g. Soluble in benzene, alcohol, ether and hydrochloric acid; insoluble in water and caustic alkali solutions.

Found %: C 73.01; H 7.71; N 4.18. $C_{21}H_{27}O_3N$. Calculated %: C 73.35; H 7.97; N 4.10.

The hydrochloride of the 3-N,N-dimethylaminopropyl ester had m.p. 108-110° (with decomp.) after recrystallization from ethyl acetate. Readily soluble in water; insoluble in anhydrous alcohol and ether.

Found %: N 3.82; Cl 9.64. $C_{21}H_{27}O_3N \cdot HCl$. Calculated %: N 3.71; Cl 9.39.

Tropyl ester of β-(4-methoxyphenyl)-α-phenylpropionic acid. To a solution of 5 g β-(4-methoxyphenyl)-α-phenylpropionyl chloride in 10 ml dry benzene was added 2.26 g tropine. The mixture was heated for 15 hours with stirring at 70°. The precipitate was filtered and washed first with benzene and then with ethyl

acetate. Recrystallization from a mixture of chloroform and ether gave 4.39 g (66%) of hydrochloride with m.p. 170-174° (decomp.). readily soluble in water and chloroform; insoluble in benzene, ether and ethyl acetate.

Found %: N 3.44; Cl 8.45. $C_{24}H_{29}O_3N \cdot HCl$. Calculated %: N 3.37; Cl 8.50.

The base liberated from the hydrochloride distills at 188-194° (1-1.5 mm) in the form of a viscous, yellow oil, readily soluble in organic solvents and acids, insoluble in water and caustic alkalies.

Found %: C 76.09; H 7.88; N 3.62. $C_{24}H_{29}O_3N$. Calculated %: C 75.94; H 7.70; N 3.69.

Tropyl ester of β-(4-acetoxyphenyl)-α-phenylpropionic acid. To a solution of 5 g of β-(4-acetoxyphenyl)-α-phenylpropionyl chloride in 15 ml dry benzene was added 2.3 g tropine. The mixture was heated with stirring at 60-65° for 15 hours. The precipitate was filtered, washed with benzene and then with ethyl acetate, and recrystallized from a mixture of chloroform and ether. Yield 4.8 g with m.p. 179° (decomp.). The hydrochloride is readily soluble in water and chloroform, insoluble in benzene, ether and ethyl acetate.

Found %: N 3.25; Cl 8.09, 8.00. $C_{25}H_{29}O_4N \cdot HCl$. Calculated %: N 3.15; Cl 7.99.

The base liberated from the hydrochloride distilled in vacuum with decomposition at 227-232° (0.2 mm) in the form of a viscous oil. Readily soluble in organic solvents and acids, insoluble in water and caustic alkalies.

Found %: N 3.25. $C_{25}H_{29}O_4N$. Calculated %: N 3.44.

2-N,N-Diethylaminoethylamide of β-(4-methoxyphenyl)-α-phenylpropionic acid. To a solution of 1.7 g 2-N,N-diethylaminoethylamine in 15 ml dry benzene was added 3 g β-(4-methoxyphenyl)-α-phenylpropionyl chloride. The solution was heated for $2^1/_2$ hours at 60°. The benzene was then taken off in vacuum and the residue was mixed with 5% caustic alkali solution and subjected to extraction with ether. After drying, the ether was driven off and the residue distilled in vacuum at 204-205° (1 mm). A viscous liquid came over and soon crystallized. M.p. 96°. Yield 2.88 g. The product is highly soluble in ether, alcohol, benzene, acetone and hot water. Insoluble in cold water and alkalies.

Found %: N 8.10, 7.60. $C_{22}H_{30}O_2N_2$. Calculated %: N 7.93.

The hydrochloride does not crystallize. Soluble in benzene, alcohol and acetone; insoluble in ethyl ether and ligroine.

Diethylaminohydroxypropyl amide of β-(4-methoxyphenyl)-α-phenylpropionic acid. A mixture of 3 g β-(4-methoxyphenyl)-α-phenylpropionyl chloride, 1.7 g 3-N,N-diethylamino-2-hydroxypropylamine and 15 ml dry benzene was heated 4 hours at 60°. After cooling, a 5% solution of hydrochloric acid was added. The aqueous layer was separated, neutralized with caustic alkali solution and extracted with ether. After drying, the ether was driven off, and the residue was distilled at 210-220° (1 mm) to give 1.81 g (43%) of a thick oil. It dissolves in organic solvents, acid and caustic alkali; insoluble in water.

Found %: N 7.10. $C_{23}H_{32}O_3N_2$. Calculated %: N 7.10.

The hydrochloride is an oil which is insoluble in benzene, ether; soluble in water.

Diethylaminobutylamide of β-(4-methoxyphenyl)-α-phenylpropionic acid. A mixture of 3 g β-(4-methoxyphenyl)-α-phenylpropionyl chloride, 1.7 g 4-N,N-diethylaminobutylamine and 20 ml dry benzene was heated 4 hours at 60°, after which the benzene was taken off in vacuum. The residue was treated with 5% caustic alkali solution and subjected to extraction with ether. After drying, the ether was driven off and the residue distilled at 214-220° (1 mm) to give 3.56 g (85%) of thick oil which rapidly crystallized; m.p. 81-83°. The product is readily soluble in organic solvents, insoluble in water and caustic alkalies.

Found %: N 7.41. $C_{24}H_{34}O_2N_2$. Calculated %: N 7.33.

SUMMARY

1. The following pharmacologically active compounds were synthesized: the 2-N,N-diethylaminoethyl,

3-N,N-dimethylaminopropyl and tropyl esters of β-(4-methoxyphenyl)-α-phenylpropionic acid; the tropyl ester of β-(4-acetoxyphenyl)-α-phenylpropionic acid; and the 2-N,N-diethylaminoethylamide, the 3-N,N-diethylamino-2-hydroxypropylamide and the 4-N,N-diethylaminobutylamide of β-(4-methoxyphenyl)-α-phenylpropionic acid and other compounds.

2. It was established that replacement of the hydroxy group by the methoxy group in β-(hydroxyphenyl)-α-phenylpropionic acid has little effect on the biological properties of alkamine esters of this acid.

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THE PROBLEM OF THE PREPARATION OF α-ALKYLNAPHTHALENES

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No general and convenient method for preparation of α-alkylnaphthalenes free from traces of β-isomers has hitherto been described in the literature. Several methods are known for the preparation of α-naphthalene [1] but they are inapplicable (or difficultly applicable) to other α-alkylnaphthalenes. For the synthesis of these compounds we found the most convenient method to consist in the dehydration of α-naphthylalkanols followed by hydrogenation of the resultant α-naphthylalkylenes.

α-Naphthylalkanols are readily formed in good yield by the Grignard reaction from α-bromonaphthalene and aldehydes or ketones. The process may be represented by the following scheme:

$$\alpha\text{-}C_{10}H_7Br \rightarrow \alpha\text{-}C_{10}H_7MgBr \rightarrow \alpha\text{-}C_{10}H_7-\underset{\displaystyle OH}{\underset{|}{C}R}-CH_2R' \rightarrow$$

$$\rightarrow \alpha\text{-}C_{10}H_7CR{=}CHR' \rightarrow \alpha\text{-}C_{10}H_7CHRCH_2R$$

R= H or alkyl; R'= H or alkyl

A fairly large number of investigations on the dehydration of α-naphthylalkanols has been reported because of the susceptibility of the resultant α-naphthylalkylenes to polymerization. Partial removal of water occurs during actual distillation of the α-naphthylalkanols, but complete dehydration is achieved only by heating and distillation in presence of catalysts (KOH, $KHSO_4$, Al_2O_3, H_2SO_4, H_3PO_4, etc.). The yield of α-naphthylalkylenes depends to a considerable extent upon their susceptibility to polymerization; the lower homologs polymerize with facility and their yield is low. Examination of the literature reveals that in each case of dehydration of an α-naphthylalkanol special conditions must be selected to obtain an optimum yield. A relatively small number of investigations have been concerned with the reduction of the unsaturated bond in the side chain of α-naphthylalkylenes; both noncatalytic [2] and catalytic [3] methods of reduction have been recommended.

Our preliminary experiments on the hydrogenation of some α-naphthylalkylenes in presence of skeletal nickel catalyst showed that best results are obtained at room temperature and atmospheric pressure, the absorption of hydrogen being nearly quantitative under these conditions.

We used the literature methods for preparation of the following substances which were of interest in connection with the synthesis of α-alkylnaphthalenes: 1-(α-naphthyl)-ethanol-1, 1-(α-naphthyl)-propanol-1, 2-(α-naphthyl)-propanol-2, and 1-(α-naphthyl)-butanol-1. We used potassium bisulfate as the agent for dehydration of these compounds. This method of dehydration of some α-naphthylalkanols was previously employed by Yu. S. Zalkind and S. A. Zonis [4], but the interests of these investigators were centered upon the susceptibility of the prepared α-naphthylalkylenes to polymerization, and they did not devote much attention to the establishment of optimum conditions of dehydration.

As was to be expected, we encountered the greatest difficulties in the preparation of α-ethylnaphthalene due to the great susceptibility of α-vinylnaphthalene to polymerization. On repeating the experiments

described in [4] (heating of α-naphthylethanol-1 with $KHSO_4$ for 4 hours at 160° and 40mm), the yield of α-vinylnaphthalene was extremely low. We therefore tried out different conditions of dehydration; distillation of α-naphthylethanol-1 in vacuum in presence of potassium bisulfate and in its absence at various temperatures and pressures, as well as in presence of polymerization inhibitors (hydroquinone).

Qualitative reactions were used to test the completeness of dehydration: reaction for the hydroxyl group, etc.). It was also useful to note the amount of hydrogen absorbed during the subsequent hydrogenation. Experiments were usually so carried out that dehydration and hydrogenation followed one another without separation of α-vinylnaphthalene as such. Results of the most significant experiments are presented in Table 1. The data show that a single distillation of 1-(α-naphthyl)-ethanol-1 at 135-160° and 15 mm (experiment 1) does not lead to complete dehydration, and the distilled substance is a mixture of original alkanol and α-vinylnaphthalene.

TABLE 1
Preparation of α-Ethylnaphthalene

Experiment number	Amount of 1-(α-naphthyl)-ethanol-1 (in g)	Number of distillations	Amount of $KHSO_4$ (g)	Residual pressure (mm)	Boiling point	Amount of substance after distillation (g)	Reaction for OH group	Amount of hydrogen (%)	Yield of α-ethylnaphthalene (in g)	Yield of α-ethylnaphthalene (in %)
1	38.5	1	–	15	135-160°	16.3	+	50	8.1	23.2
2	38.5	2	–	15	135-136	8.2	–	100	7.8	22.4
3	38.5	1	12.5	15	135-136	8.5	–	100	8.2	23.5
4	38.5	1	6.2	1	93-94	18.2	–	100	17.6	50
5	38.5	1	6.2*	1	93-96	27.0	–	100	26.2	75
6	10.0	1	2.0*	1	93-94	8.1	–	100	8	89

Complete dehydration with formation of a substance with constant boiling point was effected by redistillation of 1-(α-naphthyl)-ethanol-1 under the same conditions (experiment 2), or by a single distillation of 1-(α-naphthyl)-ethanol-1 in presence of potassium bisulfate at 135-136° and 15 mm (experiment 3). However, the yield of α-ethylnaphthalene did not exceed 23% since the greater part of the α-vinylnaphthalene was converted to polymer. The amount of α-vinylnaphthalene and in turn of α-ethylnaphthalene was greatly increased by distillation of α-naphthylethanol-1 with $KHSO_4$ under milder conditions (b.p. 93-94° at 1 mm) (experiment 4). In this case the yield of α-ethylnaphthalene rose to 50%. Still better results were obtained under the conditions of experiment 4 but with addition of hydroquinone (experiment 5). The yield of α-ethylnaphthalene then rose to 75%. A still further rise in yield to 89% was achieved by conducting the dehydration reaction under the same conditions with small amounts of 1-(α-naphthyl)-ethanol-1 (not more than 10-20 g, experiment 6).

We made use of the same method of investigation and of selection of optimum reaction conditions in the dehydration of the remaining α-naphthylalkanols that we prepared and in the subsequent hydrogenation of the α-naphthylalkylenes. In these experiments we observed a phenomenon to which attention was also briefly drawn by earlier investigators: with increasing size of molecule of α-naphthylalkanols their susceptibility to dehydration is lowered, but the susceptibility of the corresponding α-naphthylalkylenes to polymerization is enhanced. For example, in the dehydration of 1-(α-naphthyl)-propanol-1 under the conditions in which dehydration of 1-(α-naphthyl)-ethanol-1 goes completely, a mixture of naphthylpropanol and unsaturated hydrocarbon is obtained; complete dehydration is only effected by distillation of α-naphthylpropanol-1 in presence of potassium bisulfate at 146-148° and 15 mm. Still more drastic conditions are needed for dehydration of 1-(α-naphthyl)-butanol-1; in this case distillation must be preceded by heating of the substance in presence of potassium bisulfate for a period of 1-1$^1/_2$ hours at 140-145° and 30 mm.

The structure of the aliphatic chain also appears to influence the susceptibility to dehydration, since the dehydration of 2-(α-naphthyl)-propanol-2 goes under milder conditions than the dehydration of

*In presence of hydroquinone.

α-naphthylpropanol-1.

In spite of the relatively low susceptibility to polymerization of homologs of α-vinylnaphthalene, the addition of hydroquinone during their dehydration raises the yield of α-naphthylalkylenes and in turn of α-alkylnaphthalenes (Table 2).

TABLE 2
Preparation of α-Alkylnaphthalenes

Substance	Amount of starting substance (in g)			Amount of substance after distillation (g)	Boiling point	Amount of hydrogen (%)	Yield of α-alkylnaphthalene	
	α-naphthylalkanol	$KHSO_4$	hydroquinone				(in g)	(in %)
α-$C_{10}H_7CH(OH)CH_2CH_3$	46.5	16	—	26	146—148° (15 мм)	100	25.6	60
α-$C_{10}H_7CH(OH)CH_2CH_3$	46.5	16	0.26	33.8	98—100 (1 мм)	100	33.2	78
α-$C_{10}H_7COH(CH_3)_2$	37	8	—	24.4	129—130 (15 мм)	100	23.7	70
α-$C_{10}H_7COH(CH_3)_2$	37	8	0.21	27.5	103—105 (1 мм)	100	27.5	80
α-$C_{10}H_7CH(OH)CH_2CH_2CH_3$	26	8	—	21.5	140—145 (30 мм)	100	21.4	89.5
α-$C_{10}H_7CH(OH)CH_2CH_2CH_3$	26	8	0.14	23.1	140—145 (30 мм)	100	22.8	95.6

The methods of preparation of α-alkylnaphthalenes are briefly described in the experimental section.

As was indicated above, dehydration of 1-(α-naphthyl)-butanol-1 requires preliminary heating of the substance at a fairly high temperature; these conditions could possibly lead to migration of the side chain from the α-position of the naphthalene ring into the β-position. The structure of the unsaturated hydrocarbon resulting from dehydration of α-naphthyl-butanol-1 was studied by oxidation with potassium permanganate in acetone. This reaction gave only one compound—α-naphthoic acid. It was thus proven that the hydrocarbon is 1-(α-naphthyl)-butene-1 and that isomerization does not take place under the conditions in question.

We also carried out the dehydration of 1-(α-naphthyl)-butanol-1 in presence of KOH, since it was thought that this reagent might lower the temperature of the reaction and eliminate the need for preheating. Our experiments confirmed this supposition, but the substance resulting from dehydration was not pure even though it did not contain the original naphthylalkanol. It was evidently a mixture of unsaturated hydrocarbons; on hydrogenation it took up the theoretical amount of hydrogen but the reduced product did not have a constant boiling point, and only after numerous distillations did we succeed in isolating α-butylnaphthalene in a yield of 66.8% reckoned on the α-naphthyl-butanol. Oxidation of the substance obtained by dehydration gave: α-naphthoic acid (64.5%), α-naphthylacetic acid (19%) and α-naphthyl methyl ketone (7%). These results showed that dehydration of α-naphthylbutanol-1 in presence of KOH is accompanied by changes in the structure of the aliphatic chain.

The method of preparation of α-alkylnaphthalenes that we investigated has a number of advantages over other methods described in the literature: a) the synthesis has a small number of steps; b) the resultant α-alkylnaphthalenes do not contain β-isomers and polyalkylnaphthalenes; c) this method permits preparation of α-alkylnaphthalenes both with normal and with branched chains.

EXPERIMENTAL

α-Ethylnaphthalene

a) Dehydration of 1-(α-naphthyl)-ethanol-1. α-Naphthylethanol-1 (38.5 g) was distilled at a pressure of 1 mm in presence of 6.2 g potassium bisulfate and 0.25 g hydroquinone. Distillation was effected rapidly over a bare flame, no attention being paid to overheating. 27 g substance with b.p. 93-96° (1 mm) was obtained. Qualitative reactions for the hydroxyl group gave negative results; those for the unsaturated bond were positive. Qualitative tests were made with samples previously dried over sodium sulfate. Redistillation of a small quantity of the substance gave α-vinylnaphthalene with b.p. 93-94° at 1 mm; melting point of the picrate 101°.

b) Reduction of α-vinylnaphthalene. To a solution of 26.6 g of the substance with b.p. 93-96° at 1 mm in 200 ml anhydrous ethyl alcohol was added 5 g skeletal nickel catalyst in 15 ml alcohol, and the mixture was shaken in a hydrogen atmosphere at room temperature and atmospheric pressure. In the course of 15 minutes the theoretically calculated amount of hydrogen (3860 ml) was taken up. The catalyst was filtered off and washed with alcohol. The alcoholic solution was evaporated in a vacuum and the residual substance was distilled in vacuum. 26.2 g α-ethylnaphthalene was obtained with b.p. 109-110° at 9 mm (yield 75% reckoned on 1-(α-naphthyl)-ethanol-1). After redistillation with sodium the compound had b.p. 109° at 9 mm, d^{20} 1.0208, n_D^{20} 1.6069, 1.6070. M.p. of picrate 99°.

α-n-Propylnaphthalene

a) Dehydration of 1-(α-naphthyl)-propanol-1.* 46.5 g α-naphthylpropanol-1 was distilled at a pressure of 15 mm in presence of 10 g potassium bisulfate and 0.26 g hydroquinone; after cessation of frothing, distillation was continued at 1 mm pressure. 33.8 g substance was obtained with b.p. 98-100° at 1 mm; it did not contain α-naphthylpropanol-1. M.p. of picrate 110-111°.

b) Reduction of α-naphthylpropene-1. A mixture of 33.5 g substance with b.p. 98-100° at 1 mm, 5 g skeletal nickel catalyst and 150 ml alcohol was shaken in a hydrogen atmosphere at room temperature and atmospheric pressure. In the course of 25 minutes the theoretical amount of hydrogen was absorbed. The reaction mixture was worked up by the method used in the preparation of ethylnaphthalene and gave 33.2 g (78.6%) of α-propylnaphthalene with b.p. 113-114° at 6 mm. After redistillation of a specimen with metallic sodium, it had b.p. 114-114.5° at 6 mm, d^{20} 0.9902, n_D^{20} 1.6001. The picrate melted at 93°.

α-Isopropylnaphthalene

a) Dehydration of 2-(α-naphthyl)-propanol-2. 37 g 2-(α-naphthyl)-propanol-2, 12 g potassium bisulfate and 0.21 g hydroquinone were taken in the experiment. The substance was distilled first with cautious heating at 15 mm and later, after foaming had subsided, at 103-105° and a pressure of 1 mm. 27.5 g substance was obtained which did not contain 2-(α-naphthyl)-propanol-2. Redistillation of a small quantity of the substance gave α-naphthyl-2-propene with b.p. 122-123° at 10 mm. The picrate melted at 89-90°.

b) Reduction of 2-(α-naphthyl)-propene-2. 27.3 g of the substance with b.p. 103-105° at 1 mm was hydrogenated in 150 ml alcohol over 5 g skeletal nickel catalyst. After working up in the usual manner and distillation, 27.1 g (80% calculated on the naphthylpropanol) was obtained; b.p. 130-131° at 10 mm. Melting point of picrate 86°. After redistillation with sodium the b.p. was 131-131.5° at 10 mm.

1-(α-Naphthyl)-butanol-1**

A solution of 51.8 g α-bromonaphthalene in 200 ml anhydrous alcohol and 0.1 ml methyl iodide was added to 6 g magnesium; at the conclusion of the reaction, a solution of 20.6 g butyraldehyde in 100 ml

* Dehydration of homologs of α-naphthylethanol-1, which takes place at higher temperatures and pressures, is accompanied by considerable frothing of the substance, and this must be taken into account during the operation. It is desirable to heat the substance at first at a pressure of 15-30 mm and later, after frothing has subsided, and direct distillation has become possible, at a pressure of 1 mm.

** The literature [5] does not describe the method of preparation of 1-(α-naphthyl)-butanol-1 and its properties; these data are therefore given in the present paper.

anhydrous ether was added. After completion of the reaction, decomposition was effected with 18% hydrochloric acid. The reaction product was worked up in the usual manner, the ether was driven off and the residue (49.2 g) distilled in vacuum (1 mm). 2 g of crystalline substance was obtained with m.p. 78-79° (naphthalene) and 42.1 g α-naphthylbutanol-1 with b.p. 129-131° at 1 mm. After redistillation the b.p. was 130-131° at 1 mm. Yield 92%. A colorless, viscous oil, soluble in the common organic solvents, insoluble in water and aqueous solutions of acids and caustic alkalies.

Found %: C 84.04; H 7.96. $C_{14}H_{16}O$. Calculated %: C 83.95; H 8.05.

The picrate forms yellow needles (from alcohol) with m.p. 51-52°, soluble in benzene, chloroform and ether, difficultly soluble in ligroine and water.

Found %: N 9.42. $C_{20}H_{19}O_8N_3$. Calculated %: N 9.78.

α-n-Butylnaphthalene

a) Dehydration of 1-(α-naphthyl)-butanol-1. A mixture of 26 g α-naphthyl-butanol-1, 8 g potassium bisulfate and 0.14 g hydroquinone was heated for $1\frac{1}{2}$ hours at 140-145° and 30 mm. The substance was then distilled at 143-145° and 30 mm. Colorless, mobile liquid, soluble in organic solvents and insoluble in water.

Picrate: orange needles with m.p. 91-92° (from alcohol), soluble in benzene, ethyl acetate and alcohol, sparingly soluble in ligroine and gasoline.

Found %: N 10.23. $C_{20}H_{17}O_7N_3$. Calculated %: N 10.21.

b) Reduction of 1-(α-naphthyl)-butene-1. 23 g α-naphthylbutene-1 in 150 ml methyl alcohol was reduced in presence of 2.2 g skeletal nickel catalyst. Hydrogenation and working-up of the product were carried out as in the preceding similar experiments. 22.8 g α-butylnaphthalene was obtained with b.p. 148-149° at 13 mm. Yield 95.6% reckoned on the naphthylbutanol. Redistillation with sodium gave a product with b.p. 148.5-149° at 13 mm, d^{20} 0.9756, n_D^{20} 1.5872. M.p. of picrate 64-65°.

Oxidation of 1-(α-naphthyl)-butene-1. To a solution of 2.3 g α-naphthyl-butene-1 in 40 ml acetone was added 3.6 g potassium permanganate and the mixture stirred at room temperature for 10 hours. The mixture was worked up in the usual manner to give colorless crystals which were recrystallized from alcohol. 1.7 g of substance with m.p. 160-161° was obtained. No depression was observed when a mixed melting test was carried out with α-naphthoic acid. The acetone solution, remaining after separation of the manganese dioxide and potassium α-naphthoate, was evaporated to dryness. No neutral compounds were found.

Dehydration of 1-(α-naphthyl)-butanol-1 in presence of potassium hydroxide. To 1-(α-naphthyl)-butanol-1 (26 g) was added 6 g of potassium hydroxide powder and the mixture distilled in vacuum at 30 mm. Severe frothing occurred. 22 g of product with b.p. 130-140° (30 mm) was obtained; 1-(α-naphthyl)-butanol-1 was absent. The mixture of substances could not be separated into its components by numerous fractionations.

Reduction of the product with b.p. 130-140° (30 mm). To a solution of 20 g of the product in 100 ml alcohol was added 2 g skeletal nickel catalyst and reduction was carried out as in preceding experiments. The amount of hydrogen absorbed was 2460 ml (the theoretically calculated amount reckoned on the naphthylbutene). After working up in the usual manner, 19.8 g of dark-brown product was obtained; b.p. 145-153° at 13 mm; it did not give reactions for the double bond and the hydroxyl group. Three distillations gave 16 g α-n-butylnaphthalene with b.p. 148-149° at 13 mm. Yield 66.8% (calculated on the naphthylbutanol), m.p. of picrate 64-65°.

Oxidation of the product with b.p. 130-140° at 30 mm. To a solution of 4.6 g of product in 100 ml acetone was added 7.1 g potassium permanganate, and the mixture stirred at room temperature for 24 hours. Crystals were obtained after working up in the usual manner. Fractional crystallization from aqueous alcohol gave 2.8 g α-naphthoic acid with m.p. 160-161° (yield 64.5%) and 0.9 g α-naphthylacetic acid with m.p. 130-131° (yield 19.1%). The acetone solution obtained after separation of the precipitate (manganese dioxide and potassium salts of the acids) was evaporated to dryness to give 0.3 g (7%) of oily substance with positive reactions for the carbonyl group (reduces Fehling solution, forms a precipitate with hydrazine derivatives). The

semicarbazone forms colorless crystals from alcohol with m.p. 207-208°. A mixture with the semicarbazone of α-naphthyl methyl ketone (m.p. 207°) melted at 207-208°.

SUMMARY

1. A general way of preparation of α-alkylnaphthalenes (excluding α-methylnaphthalene) was studied. It involves dehydration of α-naphthylalkanols in presence of potassium bisulfate and hydroquinone and subsequent hydrogenation of the α-naphthylalkylenes in presence of skeletal nickel catalyst.

2. α-Ethyl-, α-n-propyl, α-isopropyl and α-n-butylnaphthalenes were prepared by this method in yields of 75 to 95%.

3. It was established that dehydration of α-naphthylbutanol-1 in presence of potassium hydroxide is accompanied by isomerization in the aliphatic chain.

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* T.p. = C. B. Translation pagination.

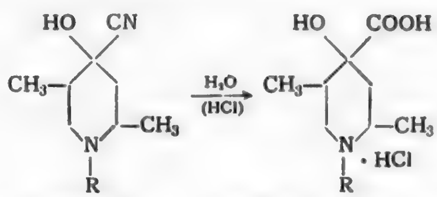
HETEROCYCLIC COMPOUNDS

46. HYDROLYSIS AND ALCOHOLYSIS OF CYANOHYDRINS OF γ-PIPERIDONES, TETRAHYDRO-γ-PYRONES AND TETRAHYDRO-γ-THIOPYRONES. SYNTHESIS OF 1-ALKYL-2,5-DIMETHYL-4-CARBALKOXY-4-PIPERIDOLS

I. N. Nazarov and B. V. Unkovsky

In the preceding communication we described the synthesis of a series of cyanohydrins of 1-alkyl-2,5--dimethyl-4-piperidones with facility and in high yield by interaction of γ-piperidones with hydrocyanic acid [1].

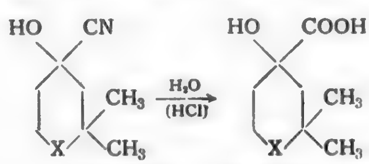
In the present paper we describe the hydrolysis of these cyanohydrins to the corresponding piperidine α--hydroxy acids on the basis of which the transition to new synthetic anesthetics of the α-eucaine [2] and α-cocaine type [3] can be readily realized. On heating with concentrated hydrochloric acid for several hours the cyanohydrins of the γ-piperidones are nearly quantitatively saponified to the corresponding 4-hydroxypiperidine--4-carboxylic acids:



R=H (I), R=CH_3 (II), R=C_2H_5 (III), R=C_3H_7 (IV), R=iso C_3H_7 (V), R=C_3H_5 (VI), R=C_4H_9 (VII), R=iso C_4H_9 (VIII), R=iso C_5H_{11} (IX), R=cycloC_6H_{11} (X), R=C_6H_5 (XI),

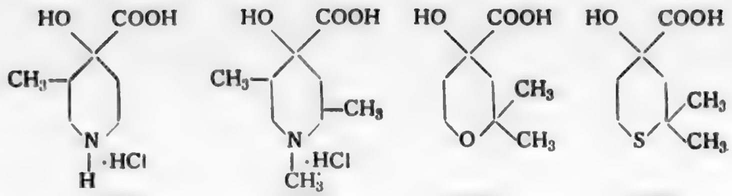
R=H (XII), R=CH_3 (XIII), R=C_2H_5 (XIV), R=C_3H_7 (XV), R=iso C_3H_7 (XVI), R=C_3H_5 (XVII), R=C_4H_9 (XVIII), R=iso C_4H_9 (XIX), R=iso C_5H_{11} (XX), R=cycloC_6H_{11} (XXI), R=C_6H_5 (XXII).

The cyanohydrins of 2,2-dimethyl-tetrahydropyran-4-one (XXIII) and 2,2-dimethyl-tetrahydrothiopyran-4-one (XXIV), described in the same paper [1], are likewise transformed with great facility under the same conditions into their corresponding hydroxy acids (XXV) and XXVI):



X=O (XXIII), X=S (XXIV), X=O (XXV), X=S (XXVI).

Some of the α-hydroxy acids that we prepared were isolated in the pure form (compounds of the piperidine series were isolated as hydrochlorides): 2,5-dimethyl-4-hydroxy piperidine-4-carboxylic acid (XII) in 63.5% yield; 1,2,5-trimethyl-4-hydroxy-piperidine-4-carboxylic acid (XIII) in 83% yield; 2,2-dimethyl-4-hydroxy-tetrahydropyran-4-carboxylic acid (XXV) in 91% yield; and 2,2-dimethyl-4-hydroxy-tetrahydrothiopyran-4-carboxylic acid (XXVI) in 83.6% yield.

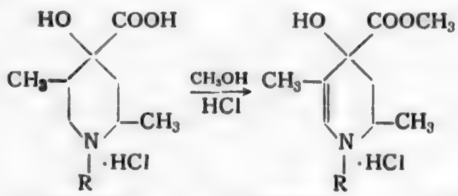


(XII) (XIII) (XXV) (XXVI)

In the remaining cases the α-hydroxy acids obtained by saponification of the cyanohydrins were not isolated, but were transformed into 4-carbalkoxy-4-piperidols without purification and separation from ammonium chloride. The reason for the necessity of transformation of the hydroxy acids into the hydroxyesters is that the anesthetic activity of cocaine and its analogs is manifested after esterification of the carboxyl group.

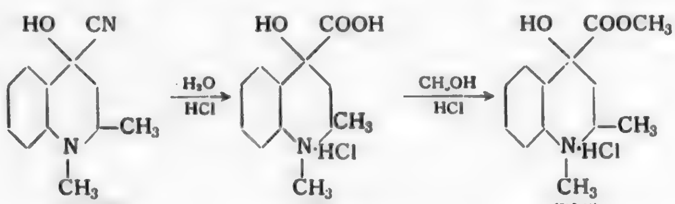
Esterification of 1-alkyl-2,5-dimethyl-4-hydroxypiperidine-4-carboxylic acids is effected by heating solutions of the hydrochlorides of the hydroxy acids in the appropriate alcohols with gentle boiling and continuous passage of a stream of dry hydrogen chloride, as was done in the esterification of ecgonine [4].

This method was used for the preparation in 70-90% yields of the following homologous series of 1-alkyl-2,5-dimethyl-4-carbomethoxy-4-piperidols, which are readily formed from the corresponding hydroxy acids by esterification with anhydrous methyl alcohol:

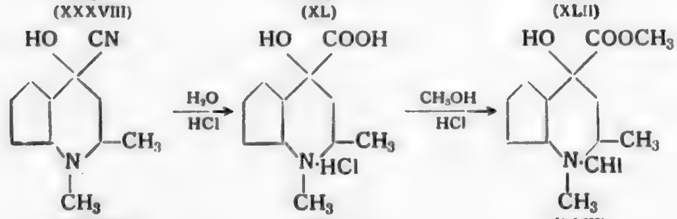


R=H (XII), R=CH_3 (XIII), R=C_2H_5 (XIV), R=C_3H_7 (XV), R=iso C_3H_7 (XVI), R=C_3H_5 (XVII), R=C_4H_9 (XVIII), R=iso C_4H_9 (XIX), R=iso C_5H_{11} (XX), R=cycloC_6H_{11} (XXI), R=C_6H_5 (XXII), R=H (XXVII), R=CH_3 (XXVIII), R=C_2H_5 (XXIX), R=C_3H_7 (XXX), R=iso C_3H_7 (XXXI), R=C_3H_5 (XXXII), R=C_4H_9 (XXXIII), R=iso C_4H_9 (XXXIV), R=iso C_5H_{11} (XXXV), R=cycloC_6H_{11} (XXXVI), R=C_6H_5 (XXXVII).

Similar transformations were realized also with bicyclic cyanohydrins (XXXVIII) and (XXXIX), saponification of which gave the corresponding hydroxy acids (XL) and (XLI); the latter are transformed with facility into their corresponding methyl esters (XLII) and (XLIII):



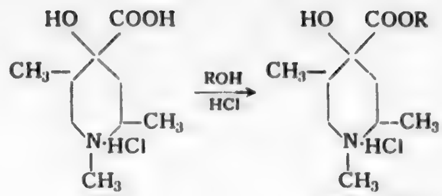
(XXXVIII) (XL) (XLII)



(XXXIX) (XLI) (XLIII)

Esterification of the hydrochlorides of 1,2,5-trimethyl-4-hydroxy-piperidine-4-carboxylic acid (XIII) with various alcohols gave 80-90% yields of a series of hydroxyesters with different alcohol radicals in the

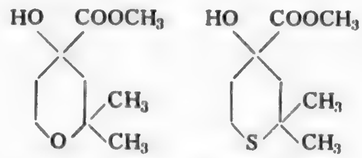
esterified carboxyl group:



(XIII)

R=C_2H_5 (XLIV), R=C_3H_7 (XLV), R=C_4H_9 (XLVI), R=iso C_5H_{11} (XLVII).

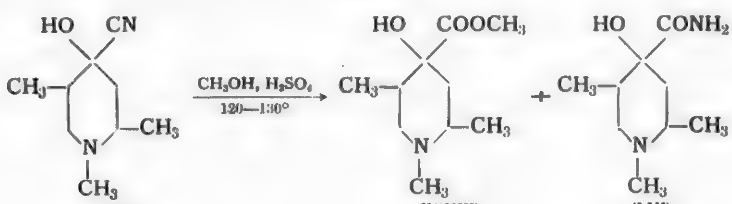
Oxygen- and sulfur-containing α-hydroxy acids (XXV) and (XXVI) were transformed by an analogous method into the corresponding methyl esters (XLVIII) and (XLIX) in a yield of 61 and 72% respectively:



(XLVIII) (XLIX)

In a number of cases the piperidinic hydroxy esters that we synthesized were crystalline products, while the hydroxy esters (XXIX-XXXVII) (R from C_2H_5 to C_6H_5) were isolated in the form of viscous oils whose yields dropped to 50-70% due to formation, during esterification of the hydroxy acids, of low-boiling secondary products which were not subjected to investigation. The transformation of piperidinic α-hydroxy acids into hydroxyesters is also accompanied during the process of esterification by formation of other secondary products, usually appearing on separation of the free bases and having the form of dark oils insoluble in ether. The latter are usually formed during esterification of the α-hydroxy acids with methyl alcohol at temperatures above 80°, and under these conditions they are often the main product of the reaction.

Apart from the study of the esterification of hydroxy acids and their transformation into 4-carbalkoxy-4--piperidols, great interest was attached to direct transformation of cyanohydrins into hydroxy esters by alcoholysis of the nitrile group, realizable in practice in a single step. Heating in a sealed tube of a solution of cyanohydrin (II) in anhydrous methanol with concentrated sulfuric acid by the known method [5] leads to a 70% yield of 1,2,5-trimethyl-4-carbomethoxy-4-piperidol (XXVIII) side by side with the amide (LVI) in 21% yield; the latter is formed by partial hydration of the nitrile group:



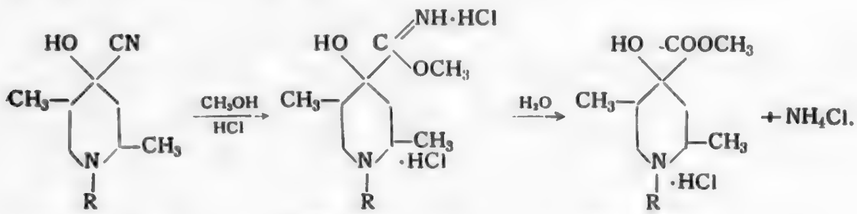
(II) (XXVIII) (LVI)

4-Carbalkoxy-4-piperidols can likewise be obtained directly in one operation by alcoholysis of cyanohydrins of γ-piperidones in presence of dry hydrogen chloride to form the hydrochlorides of iminoethers [6], which are then subjected to acid hydrolysis.

Formation of iminoethers usually proceeds satisfactorily, but in the case of aminonitriles it is sometimes accompanied by serious preparative difficulties associated with the poor solubility of the resultant salts in alcohols [6, 7]. Cyanohydrins (I), (III) and (IV) are scarcely amenable to alcoholysis by this method since treatment with an equimolar amount of the anhydrous alcohol and hydrogen chloride leads to formation of the

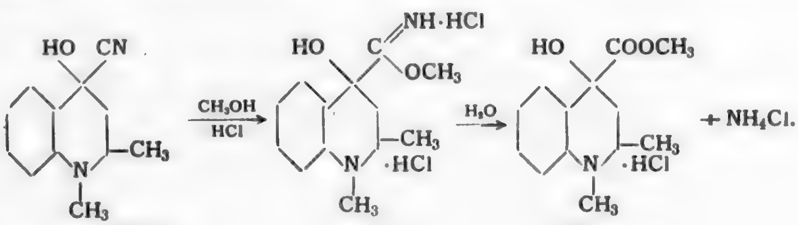
alcohol-insoluble hydrochlorides of these cyanohydrins; the latter are precipitated and their transformation into iminoethers goes extremely slowly and incompletely.

The employment of an excess of alcohol already saturated with hydrogen chloride also fails to lead to transformation of cyanohydrins into iminoethers under the conditions indicated. Saturation of solutions of cyanohydrins (II) and (X) in anhydrous methanol with dry hydrogen chloride readily leads to formation of the hydrochlorides of the corresponding iminomethyl ethers (LI) and (LII), which on subsequent acidification with hydrochloric acid and shaking with glacial acetic acid for 30-40 minutes are gradually transformed into the hydroxyesters (XXVIII) and (XXXVI) in 75-80% yield.



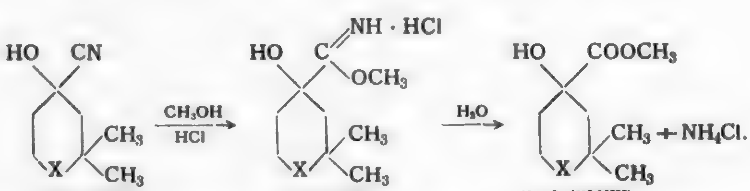
R=CH_3 (II), R=cycloC_6H_{11} (X), R=CH_3 (LI), R=cycloC_6H_{11} (LII), R=CH_3 (XXVIII), R=cycloC_6H_{11} (XXXVI).

The bicyclic cyanohydrin (XXXVIII) can be converted by this route into the corresponding hydroxyester (XLII) in 76% yield:



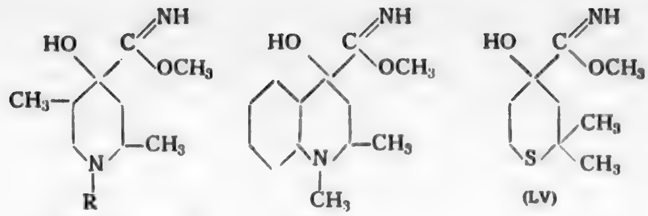
(XXXVIII) (LIII) (XLII)

Alcoholysis by this method of cyanohydrins of oxygen- and sulfur-containing heterocyclic γ-ketones (XXIII) and (XXIV) leads to smooth formation of the hydrochlorides of the corresponding iminomethyl ethers, hydrolysis of which gives the hydroxyesters (XLVIII) and (XLIX) in 52% and 74% yield:



X=O (XXIII), X=S (XXIV), X=O (LIV), X=S (LV), X=O (XLVIII), X=S (XLIX).

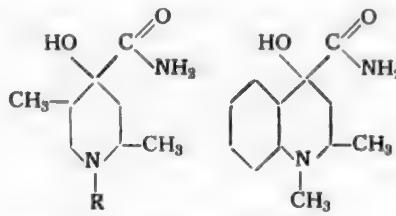
By careful treatment of the solutions of hydrochlorides of the iminoethers with potassium carbonate, it was possible to isolate the individual crystalline bases of the iminomethyl ethers (LI), (LII), (LIII) and (LV) which were found to be perfectly stable towards alkaline carbonates.



R=CH_3 (LI), R=cyclo C_6H_{11} (LII). (LIII) (LV)

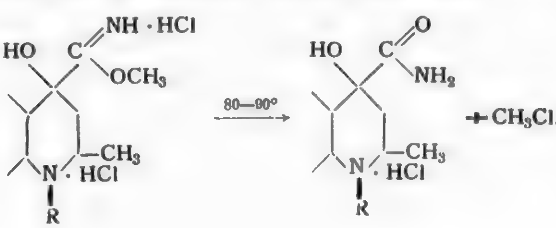
Alcoholysis of the cyanohydrins (II), (X) and (XXVIII) via the iminoethers (LI), (LII) and (LIII) does not always go smoothly, because the hydrochlorides of these iminoethers are exceptionally sensitive to hydrolytic conditions; in some experiments this led to the quantitative separation not of the anticipated hydroxyesters (XXVIII), (XXXVI) and (XLII) but of the amides of the corresponding hydroxy acids (LVI), (LVII) and (LVIII). To a slight extent this reaction accompanies the hydrolysis of nearly all hydrochlorides of the iminoethers.

The amides of the following acids were isolated and characterized during the investigation: 1,2,5-trimethyl-4-hydroxypiperidine-4-carboxylic acid (LVI); 1-cyclohexyl-2,5-dimethyl-4-hydroxypiperidine-4-carboxylic acid (LVII); and 1,2-dimethyl-4-hydroxydecahydroquinoline-4-carboxylic acid (LVIII):



R=CH_3 (LVI), R=cyclo C_6H_{11} (LVII). (LVIII)

It was shown that the hydrochlorides of the iminomethyl ethers (LI),(LII) and (LIII) easily lose a molecule of methyl chloride when heated in anhydrous methanol at 80-90° for 2-3 hours and are quantitatively transformed into the corresponding amides of the hydroxy acids (LVI), (LVII) and (LVIII):



A similar behavior on heating in anhydrous alcohols is exhibited by iminoethers obtained from other cyanohydrins, e. g. from benzaldehyde cyanohydrin [8], also from various nitriles [9, 12], and in some cases the removal of the alkyl halide goes with such facility that it proceeds even at room temperature [13].

This phenomenon is nevertheless not general for all iminoethers, since many nitriles normally enter into reaction during alcoholysis and form stable iminoethers whose acid hydrolysis usually leads to esters but not amides.

EXPERIMENTAL

2,5-Dimethyl-4-hydroxypiperidine-4-carboxylic acid (XII). A mixture of 10 g 2,5-dimethyl-4-cyano-4-piperidol (I) (m.p. 103-105°) and 30 ml concentrated hydrochloric acid was heated on a boiling water bath for 20 hours. The solution was evaporated in a porcelain dish on a water bath, the residue was extracted with two

portions (each of 25 ml) of boiling anhydrous alcohol, and the hot solution was filtered from ammonium chloride. Cooling of the alcoholic solution gave a finely crystalline precipitate which was filtered, washed with cold alcohol and dried in a vacuum-desiccator. There was obtained 8.6 g of the hydrochloride of 2,5-dimethyl-4-hydroxypiperidine-4-carboxylic acid (XII), which after recrystallization from concentrated hydrochloric acid formed hard, lustrous prisms melting at 269-270° (decomp.).

Found %: N 6.93, 6.83. $C_8H_{16}O_3NCl$. Calculated %: N 6.69.

An additional 3.1 g of less pure hydrochloride of the hydroxy acid (XII) was isolated from the alcoholic mother liquor.

1,2,5-Trimethyl-4-hydroxypiperidine-4-carboxylic acid (XIII). A mixture of 20 g 1,2,5-trimethyl-4-cyano--4-piperidol (II) (m.p. 128-129°) and 60 ml concentrated hydrochloric acid was heated 10 hours on a boiling water bath. After evaporation of the solution in a porcelain dish on the boiling water bath, the solid residue was treated with 50% sodium hydroxide until alkaline, heated until ammonia ceased to come off, acidified with hydrochloric acid and again evaporated to dryness. The solid residue was extracted three times with boiling anhydrous alcohol (25 ml portions), and the hot solution was filtered from sodium chloride. Slow cooling of the solution led to deposition of 19.3 g of the hydrochloride of 1,2,5,-trimethyl-4-hydroxypiperidine-4-carboxylic acid (XIII) in the form of lustrous prisms melting at 247-249° (decomp.). A further 3.9 g of less pure product was isolated from the mother liquor.

Found %: N 6.35, 6.07. $C_9H_{18}O_3NCl$. Calculated %: N 6.26.

2,2-Dimethyl-4-hydroxytetrahydropyran-4-carboxylic acid (XXV). A mixture of 6 g of the cyanohydrin of 2,2-dimethyltetrahydropyran-4-one (XXIII) (m.p. 84-85°) and 15 ml concentrated hydrochloric acid was heated 4 hours on a boiling water bath. A voluminous flocculent precipitate came down on cooling and was dissolved by addition of 5 ml water. The solution was extracted 5 times with ether, saturated with sodium chloride and again extracted with ether. The combined ether extracts were dried with sodium sulfate. The residue after removal of the ether soon crystallized. Yield 6.3 g 2,2-dimethyl-4-hydroxytetrahydropyran-4-carboxylic acid (XXV), which after two recrystallizations from benzene had the form of lustrous needles, melting at 109-110°.

Found %: C 55.85, 55.60; H 8.17, 8.13. $C_8H_{14}O_4$. Calculated %: C 55.17; H 8.04.

2,2-Dimethyl-4-hydroxytetrahydrothiopyran-4-carboxylic acid (XXVI). A mixture of 5 g of the cyanohydrin of 2,2-dimethyltetrahydrothiopyran-4-one (XXIV) (m.p. 76-77.5°) and 19 ml concentrated hydrochloric acid was heated on a boiling water bath for 3 hours. Dark-colored, heavy, oily drops gradually appeared at the bottom of the flask. The product was worked up as described above to give 4.6 g of the hydroxy acid (XXVI) in the form of a dark oil which soon crystallized completely. After two recrystallizations from benzene the substance had the form of colorless platelets with a mother-of-pearl sheen; m.p. 107-108°.

Found %: C 50.66, 50.84; H 7.70, 7.83; S 16.57, 16.72. $C_8H_{14}O_3S$. Calculated%: C 50.52; H 7.37; S 16.83.

Iminomethyl ether of 1,2,5-trimethyl-4-hydroxypiperidine-4-carboxylic acid (LI). 5 g of finely pulverized cyanohydrin of 1,2,5-trimethyl-4-piperidone (III) (m.p. 128-129°) was mixed with 5 ml anhydrous methanol, and dry hydrogen chloride was passed into the mixture until saturated (while cooling with ice and salt). After 10 minutes the cyanohydrin had completely gone into solution and with continued passage of hydrogen chloride the solution thickened appreciably. The following day the viscous syrup was dissolved in 30 ml water, 50 ml ether was added, and the solution (well-cooled) was saturated with potassium carbonate). The base separated out and was extracted with ether and dried with sodium sulfate. Removal of the ether left 4.5 g of iminoether (LI) which after two recrystallizations from acetone had the form of transparent, arrow-shaped crystals, losing their transparency when dried in a vacuum-desiccator; m. p. 105-106°.

Found %: N 13.70, 13.83. $C_{10}H_{20}O_2N_2$. Calculated %: N 14.00.

Other iminomethyl ethers were prepared in similar fashion.

Iminomethyl ether of 1-cyclohexyl-2,5-dimethyl-4-hydroxypiperidine-4-carboxylic acid (LII). The action of dry hydrogen chloride on a solution of 5 g cyanohydrin of 1-cyclohexyl-2,5-dimethyl-4-piperidol (X) (m.p. 108-109°) in 5 ml anhydrous methanol gave the hydrochloride of the iminoether (LII), which gradually crystallized in the form of lustrous needles. Treatment with potassium carbonate as described above gave 4.8 g base (LII), 2

recrystallizations of which from acetone gave stout plates which lost their transparency and luster when kept in a vacuum-desiccator and melted at 116-117°.

Found %: N 10.70, 10.61. $C_{15}H_{28}O_2N_2$. Calculated %: N 10.41.

Iminomethyl ether of 1,2-dimethyl-4-hydroxydecahydroquinoline-4-carboxylic acid (LIII). Reaction of dry hydrogen chloride with a solution of 5 g 1,2-dimethyl-4-hydroxy-4-cyanodecahydroquinoline (XXXVIII) (m.p.119-120°) in 5 ml anhydrous methanol gave the hydrochloride of the iminoether (LIII). This was worked up in the usual manner to give an oily base which soon crystallized completely. Yield 4.2 g iminoether (LIII); 2 recrystallizations from acetone-alcohol mixture gave snow-white, soft needles melting at 101-102°.

Found %: N 11.69, 11.68. $C_{13}H_{23}O_2N_2$. Calculated %: N 11.66.

Iminomethyl ether of 2,2-dimethyl-4-hydroxytetrahydrothiopyran-4-carboxylic acid (LV). Dry hydrogen chloride was passed into a solution of 5 g of the cyanohydrin of 2,2-dimethyltetrahydrothiopyran-4-one (XXIV) (m.p.76-76.5°) in 5 ml anhydrous methanol. The hydrochloride of the iminoether (LV) was thus obtained and was worked up to the base in the usual manner. 4.2 g of iminoether (LV) was obtained; after recrystallization from gasoline (b.p. 80-100°) it formed stout, lustrous prisms melting at 129.5-130.5°.

Found %: C 53.00, 52.92; H 8.43, 8.27; S 15.68, 15.80. $C_9H_{17}O_2NS$. Calculated %: C 53.25; H 8.37; S 15.75.

1,2,5-Trimethyl-4-hydroxypiperidine-4-carboxylic acid amide (LVI). 5 g of the cyanohydrin of 1,2,5--trimethyl-4-piperidone (II) (m.p. 128-129°) was mixed with 5 ml anhydrous methanol and converted by the action of dry hydrogen chloride into the hydrochloride of the iminomethyl ether (LI). The viscous syrup was heated for 2 hours on a water bath with gentle boiling of the mixture, after which the whole of the reaction mass solidified due to formation of a white crystalline substance. The crystals were filtered from methanol, dissolved in 20 ml water and treated with saturated potassium carbonate solution. The white, flocculent precipitate was filtered and dried in a vacuum-desiccator. 5.5 g of amide (LVI) was obtained; long, soft, snow-white crystals (from acetone or ethanol), m.p. 221° (decomp.).

Found %: N 15.10, 15.40. $C_9H_{18}O_2N_2$. Calculated %: N 15.05.

Amide of 1-cyclohexyl-2,5-dimethyl-4-hydroxypiperidine-4-carboxylic acid (LVII). The action of dry hydrogen chloride on a solution of 5 g 1-cyclohexyl-2,5-dimethyl-4-cyano-4-piperidol (X) (m.p. 108-109°) in 5 ml anhydrous methanol gave the hydrochloride of the iminoether (LII) which crystallized in the form of lustrous needles. After heating for 2 hours at 70-80°, the compound went into solution and then gradually commenced to deposit the crystalline hydrochloride of the amide (LVII) which after filtration, drying in a vacuum-desiccator and recrystallization from anhydrous alcohol formed lustrous prisms melting at 174-175°.

Found %: N 9.82, 9.57. $C_{14}H_{26}O_2N_2$. Calculated %: N 9.68.

The base of the amide (LVII), isolated in the usual manner from the hydrochloride, was recrystallized from gasoline (b.p. 80-100°) to form stout rhombic crystals melting at 114-116°.

Found %: N 11.19, 11.20. $C_{14}H_{26}O_2N_2$. Calculated %: N 11.00.

Amide of 1,2-dimethyl-4-hydroxydecahydroquinoline-4-carboxylic acid (LVIII). 5 g of 1,2-dimethyl-5-hydroxy-4-cyanodecahydroquinoline (XXXVIII) (m.p. 119-120°) in 5 ml anhydrous methanol was converted to the hydrochloride of the iminoether (LIII) by treatment with hydrogen chloride. The viscous syrup was heated 3 hours on a water bath with gentle boiling. The usual treatment gave 5.2 g amide (LVIII) which after 2 recrystallizations from acetone formed soft, white needles melting at 212° (with decomp.).

Found %: N 12.60, 12.45. $C_{12}H_{22}O_2N_2$. Calculated %: N 12.40.

2,5-Dimethyl-4-carbomethoxy-4-piperidol (XXVII). 15 g 2,5-dimethyl-4-cyano-4-piperidol (I) (m.p. 103-104°) and 55 ml concentrated hydrochloric acid were heated 20 hours on a boiling water bath. The excess hydrochloric acid was removed in vacuum. The semisolid mixture of hydrochloride of hydroxy acid (XII) and ammonium chloride was dissolved in 70 ml anhydrous methanol and heated 2 hours with gentle boiling of the methanol and with simultaneous introduction of dry hydrogen chloride. After cooling, the ammonium chloride was filtered off and the methanol driven off in a low vacuum. The viscous residue was dissolved in 50 ml water

and treated with potassium carbonate. The supernatant oily base was extracted with ether and the aqueous layer was saturated with potassium carbonate and again extracted with several portions of ether. The ether was driven off from the combined extracts after drying with sodium sulfate. Yield 13.6 g of the oily hydroxyester (XXVII) which quickly crystallized. Two recrystallizations from acetone gave lustrous prisms with m. p. 107-108°.

Found%: N 7.81, 7.51. $C_9H_{17}O_3N$. Calculated %: N 7.48.

The hydrochloride was recrystallized twice from anhydrous alcohol: lustrous, stout prisms melting at 212-214° (decomp.).

Found %: N 6.42, 6.23. $C_9H_{18}O_3NCl$. Calculated %: N 6.26.

1,2,5-Trimethyl-4-carbomethoxy-4-piperidol (XXVIII). a) 10 g of the cyanohydrin of 1,2,5-trimethyl-4-piperidone (II) (m.p.128-129°) was saponified by heating for 10 minutes on a boiling water bath with 30 ml concentrated hydrochloric acid. After removal of the hydrochloric acid in vacuum the resultant hydrochloride of the hydroxy acid (XIII), without separation from ammonium chloride and purification, was esterified as described above with 100 ml anhydrous methanol while dry hydrogen chloride was being passed into the solution. The product was worked up as in the preceding experiment; yield 10.4 g (87.2%) of hydroxyester (XXVIII) which after recrystallization from acetone formed beautiful, lustrous plates melting at 117-118°.

Found %: C 59.62, 59.82; H 9.08, 9.68; N 7.00, 7.09. $C_{10}H_{19}O_3N$. Calculated %: C 59.70; H 9.45; N 6.97.

The hydrochloride formed colorless prisms (from anhydrous alcohol). M.p. 150-151° (with decomp.).

Found %: N 5.78, 6.16. $C_{10}H_{20}O_3NCl$. Calculated %: N 5.90.

b) Into a mixture of 10 g finely pulverized cyanohydrin of 1,2,5-trimethyl-4-piperidone (II) (m.p. 128-129°) and 10 ml anhydrous methanol, cooled with ice and salt, was passed dry hydrogen chloride for $1^1/_2$ hours. The cyanohydrin completely went into solution after 15 minutes and the solution thickened gradually. The methanol solution of the hydrochloride of the iminomethyl ether (LI) was cooled overnight. The following day the reaction mixture, dissolved in 100 ml iced water and acidified with hydrochloric acid, was shaken for 40 minutes and then (with thorough cooling) saturated with potassium carbonate. The oily base that separated out was extracted 5 times with ether and the combined ether extracts were dried with calcined sodium sulfate. After removal of the ether, the oily residue quickly crystallized. Yield 9.2 g (76.8%) of hydroxyester (XXVIII) which, after recrystallization from acetone or gasoline, melted at 117-118° and did not give a depression in admixture with a specimen from the preceding experiment.

c) Into a 200 ml glass ampoule were charged 10 g cyanohydrin of 1,2,5-trimethyl-4-piperidone (II) (m.p. 128-129°) and 19.2 g anhydrous methanol; to the mixture was gradually added (while cooling with ice and salt) 5.9 g concentrated sulfuric acid (d 1.84), whereupon the cyanohydrin quickly went into solution. The reaction mass was heated 5 hours at 130-140°. The methanol was distilled off in vacuum, the viscous residue was dissolved in 20 ml water, and the base was separated with saturated potassium carbonate solution and extracted with ether; the combined ether extracts were dried with calcined sodium sulfate. 8.35 g of hydroxyester (XXVIII) was obtained; m.p. 117-118° (from acetone); no depression in admixture with the preceding specimens. This experiment also yielded 2.1 g of the ether-insoluble amide of 1,2,5-trimethyl-4-hydroxy-4-piperidinecarboxylic acid (LVI) which melted at 220° (decomp.) after recrystallization from ethyl acetate and did not give a depression in admixture with the specimen of amide (LVI) prepared as above.

1,2,5-Trimethyl-4-carbethoxy-4-piperidol (XLIV). 12 g cyanohydrin of 1,2,5-trimethyl-4-piperidone (II) (m.p. 128-129°) was saponified to the hydroxy acid (XIII) by heating for 10 hours on a boiling water bath with 45 ml concentrated hydrochloric acid. After removal of the excess hydrochloric acid in vacuum, the solid residue was dissolved in 100 ml anhydrous ethyl ester and esterified by the method described for the preparation of the hydroxyester (XXVII). Working up in the usual manner gave 11 g crystalline hydroxyester (XLIV) with m.p. 55-56° when recrystallized from gasoline (b.p. 80-90°).

Found %: N 6.68, 6.75. $C_{11}H_{21}O_3N$. Calculated %: N 6.51.

The methiodide melted at 193-194° after two recrystallizations from acetone.

Found %: N 3.84, 4.12. $C_{12}H_{24}O_3NI$. Calculated %: N 3.92.

1,2,5-Trimethyl-4-carbopropoxy-4-piperidol (XLV). The hydroxy acid (XIII), obtained by saponification of 15 g cyanohydrin of 1,2,5-trimethyl-4-piperidone (II) (m.p. 128-129°), was esterified in the usual manner by heating with 100 ml propyl alcohol at 120-130° with passage of hydrogen chloride into the reaction mixture for 4 hours. The usual treatment yielded 16.2 g of hydroxyester (XLV) which formed stout, transparent, hard needles (from methylethyl ketone) with m.p. 51-52°.

Found %: N 6.24, 6.40. $C_{12}H_{23}O_3N$. Calculated %: N 6.11.

1,2,5-Trimethyl-4-carbobutoxy-4-piperidol (XLVI). 15 g of the cyanohydrin of 1,2,5-trimethyl-4-piperidone (II) was saponified by the usual procedure to the hydroxy acid (XIII) which was then esterified by heating with 100 ml butyl alcohol for 3 hours at 115-120° with continuous passage into the reaction mixture of dry hydrogen chloride. The usual treatment yielded 18.1 g of hydroxyester (XLVI) in the form of a pale-green oil with a characteristic amine odor, b.p. 113-116° (3.5 mm). After distillation the product quickly crystallized to a snow-white mass of long, silky needles. After recrystallization from methylethyl ketone the hydroxyester (XLVI) forms hard, transparent prisms with m.p. 49-50°.

Found %: N 5.82, 5.58. $C_{13}H_{25}O_3N$. Calculated %: N 5.76.

The methiodide forms lustrous rosettes (from acetone); m. p. 120-121°.
Found %: N 3.58, 3.32. $C_{14}H_{28}O_3NI$. Calculated %: N 3.63.

1,2,5-Trimethyl-4-carboisoamyloxy-4-piperidol (XLVII). 15 g of cyanohydrin of 1,2,5-trimethyl-4-piperidone (II) (m.p. 127-128°) was saponified by the usual procedure to the hydroxy acid (XIII) which was then esterified by heating for 2 hours with 100 ml isoamyl alcohol at 130-140° and passage of dry hydrogen chloride into the reaction mixture. Working up as usual gave 12.8 g of hydroxyester (XLVII) as a viscous, pale-green liquid with a characteristic odor. After two fractionations the b.p. was 118-120° (3.5 mm).

Found %: N 5.49, 5.53. $C_{14}H_{27}O_3N$. Calculated %: N 5.44.

The methiodide forms needle-like rosettes (from anhydrous alcohol) with m.p. 199-200°.

Found %: N 3.64, 3.66. $C_{15}H_{30}O_3NI$. Calculated %: N 3.50.

1-Ethyl-2,5-dimethyl-4-carbomethoxy-4-piperidol (XXIX). 10 g of 1-ethyl-2,5-dimethyl-4-cyano-4-piperidol (III) (m.p. 98-99°) was saponified to the hydroxy acid (XIV) by the usual method and esterified with methyl alcohol as described in the experiment on the preparation of the hydroxyester (XXVII). The usual treatment gave 8.7 g oil which was fractionated in vacuum to give the following fractions: 1) b.p. 65-92° (2.5 mm), n_D^{20} 1.4632, 1.1 g; 2) b.p. 92-95° (2.5 mm), n_D^{20} 1.4722, 7.1 g. The hydroxyester (XXIX) was isolated by redistillation of the second fraction. B. p. 91-93° (2.5 mm), n_D^{20} 1.4730.

Found %: N 6.62, 6.51. $C_{11}H_{21}O_3N$. Calculated %: N 6.51.

The hydrochloride (recrystallized from acetone) melts at 150-151° (decomp.).

Found %: N 5.54, 5.47. $C_{11}H_{22}O_3NCl$. Calculated %: N 5.60.

1-Propyl-2,5-dimethyl-4-carbomethoxy-4-piperidol (XXX). 15 g 1-propyl-2,5-dimethyl-4-cyano-4-piperidol (IV) (m.p. 93-94°) was saponified in the usual manner to the corresponding hydroxy acid (XV), and the latter (without purification) was esterified with methanol by the procedure used for the hydroxyester (XXVII). The usual treatment gave 13.1 g substance which was distilled in vacuum: 1) b.p. 70-100° (5 mm), n_D^{20} 1.4636, 1.3 g; 2) b.p. 100-106° (3.5 mm), n_D^{20} 1.4695, 2.8 g; 3) b.p. 106-110° (3.5 mm), n_D^{20} 1.4700, 8.2 g.

The third fraction — hydroxyester (XXX) — is a viscous, nearly colorless liquid with a characteristic amine odor. Redistillation gave b.p. 102-103° (3 mm), n_D^{20} 1.4708.

Found %: C 62.61, 63.00; H 10.13, 10.45. $C_{12}H_{23}O_3N$. Calculated %: C 62.88; H 10.00.

1-Isopropyl-2,5-dimethyl-4-carbomethoxy-4-piperidol (XXXI). The hydroxy acid (XVI), prepared by saponification of 10 g 1-isopropyl-2,5-dimethyl-4-cyano-4-piperidol (V), was esterified by the usual procedure with methyl alcohol. 10.8 g oily hydroxyester (XXXI) was obtained and was distilled in vacuum: 1) b.p. 73-96° (3 mm), n_D^{20} 1.4631, 2.6 g; 2) b.p. 96-101° (3 mm), n_D^{20} 1.4700, 7.5 g.

The 2nd fraction — hydroxyester (XXXI) — is a viscous, yellowish-green liquid with a characteristic amine odor. Two redistillations in vacuum gave b.p. 98-100° (3 mm), n_D^{20} 1.4735.

Found %: N 6.16, 5.94. $C_{12}H_{23}O_3N$. Calculated %: N 6.11.

The hydrochloride (recrystallized from acetone) forms stout, hard crystals with m.p. 218-220° (with decomp).

Found %: N 5.12, 5.36. $C_{12}H_{24}O_3NCl$. Calculated %: N 5.25.

1-Allyl-2,5-dimethyl-4-carbomethoxy-4-piperidol (XXXV). The hydroxy acid (XVII), prepared by saponification of 15 g 1-allyl-2,5-dimethyl-4-cyano-4-piperidol (VI) (m.p. 74-76°), was esterified in the usual manner with methyl alcohol and the ester was worked up as usual to give 11.8 g of oil which gave the following fractions on distillation in vacuum: 1) b.p. 67-90° (2.5 mm), n_D^{20} 1.4760, 0.9 g; 2) b.p. 90-98° (2.5 mm), n_D^{20} 1.4798, 2.1 g; 3) b.p. 98-101° (2.5 mm), n_D^{20} 1.4822, 8.2 g.

The third fraction – the hydroxyester (XXXII) – is a viscous, colorless liquid with a characteristic amine odor, boiling after refractionation at 98-99.5° (2.5 mm), n_D^{20} 1.4827.

Found %: C 63.36, 63.25; H 9.64, 9.48. $C_{12}H_{21}O_3N$. Calculated %: C 63.43; H 9.25.

Methiodide: lustrous prisms (from anhydrous alcohol), m.p. 175° (decomp.)

Found %: N 3.83, 3.74. $C_{13}H_{24}O_3NI$. Calculated %: N 3.79.

1-Butyl-2,5-dimethyl-4-carbomethoxy-4-piperidol (XXXIII). 15 g 1-butyl-2,5-dimethyl-4-cyano-4-piperidol (VII) (m.p. 85-87°) was saponified to the corresponding hydroxy acid (XVIII) which was then esterified with methyl alcohol. By the usual treatment, 13.4 g oily product was obtained. This was distilled in vacuum to give the following fractions: 1) b.p. 77-105° (3.5 mm), n_D^{20} 1.4632, 1.2 g; 2) b.p. 105-109° (3.5 mm), n_D^{20} 1.4672, 2.2 g; 3) b.p. 109-113° (3.5 mm), n_D^{20} 1.4680, 9.2 g.

The 3rd fraction – the hydroxyester (XXXIII) – is a viscous, amber-colored liquid, boiling after redistillation at 111-113° (4 mm), n_D^{20} 1.4682.

Found %: C 63.92, 64.00; H 10.38, 10.05. $C_{13}H_{25}O_3N$. Calculated %: C 64.19; H 10.28.

Methiodide: prisms (from anhydrous alcohol), m.p. 197-198°.

Found %: N 3.53, 3.47. $C_{14}H_{28}O_3NI$ Calculated %: N 3.63.

1-Isobutyl-2,5-dimethyl-4-carbomethoxy-4-piperidol (XXXIV). 15 g of oily 1-isobutyl-2,5-dimethyl-4-cyano-4-piperidol (VIII) was saponified to the hydroxy acid (XIX) which was esterified (without separation and purification) with methanol by the usual method. Yield 13.7 g oily product. This was fractionated in vacuum: 1) b.p. 81-96°, n_D^{20} 1.4583, 1.4 g; 2) b.p. 96-101°, n_D^{20} 1.4608, 2.8 g; 3) b.p. 101-103°, n_D^{20} 1.4638, 9.1 g.

The third fraction – the hydroxyester (XXXIV) – is a viscous, yellowish green liquid, boiling after redistillation at 101-102° (3 mm), n_D^{20} 1.4644.

Found %: N 5.56, 5.59. $C_{13}H_{25}O_3N$. Calculated %: N 5.72.

1-Isoamyl-2,5-dimethyl-4-carbomethoxy-4-piperidol (XXXV). 15 g 1-isoamyl-2,5-dimethyl-4-cyano-4-piperidol (IX) (m.p. 85-87°) was saponified to the hydroxy acid (XX); esterification of the latter with methanol gave 13.8 g product which by vacuum fractionation yielded the following fractions: 1) b.p. 84-95° (3 mm), n_D^{20} 1.4604, 1.5 g; 2) b.p. 95-108° (2 mm), n_D^{20} 1.4645, 2.5 g; 3) b.p. 108-113° (2 mm), n_D^{20} 1.4680, 9.3 g.

The third fraction – the hydroxyester (XXXV) – is a viscous, yellowish green liquid, boiling after redistillation at 110-112° (2 mm), n_D^{20} 1.4689.

Found %: N 5.66, 5.69. $C_{14}H_{27}O_3N$. Calculated %: N 5.44.

Methiodide: white crystals (from anhydrous alcohol; m.p. 179-180° (decomp.).

Found %: N 3.44, 3.46. $C_{15}H_{30}O_3NI$. Calculated %: N 3.50.

1-Cyclohexyl-2,5-dimethyl-4-carbomethoxy-4-piperidol (XXXVI). 20 g of 1-cyclohexyl-2,5-dimethyl-4-cyano-4-piperidol (X) (m.p. 108-109°) was saponified to the hydrochloride of the corresponding acid (XXI) which was then esterified with methyl alcohol to give 19.8 g of oil. Vacuum fractionation of the latter gave:

1) b.p. 141-148°, n_D^{20} 1.4875, 3 g; 2) b.p. 149-155°, n_D^{20} 1.4932, 15.2 g.

The second fraction – the hydroxyester (XXXVI) – is a viscous, yellowish green liquid with a weak amine odor, b.p. after redistillation 149-151° (2,5 mm), n_D^{20} 1.4934.

Found %: N 5.44, 5.45. $C_{15}H_{27}O_3N$. Calculated %: N 5.20.

Methiodide: stout, hard crystals (from anhydrous alcohol), m.p. 205° (decomp.).

Found %: N 3.52, 3.61. $C_{16}H_{30}O_3NI$. Calculated %: N 3.40.

1-Phenyl-2,5-dimethyl-4-carbomethoxy-4-piperidol (XXXVIII). 21 g 1-phenyl-2,5-dimethyl-4-cyano-4-piperidol (XI) (m.p. 143-144°) was saponified to hydroxy acid (XXII) which was then esterified with methanol to give 19.4 g of oily product, dark in color and with an unpleasant odor. Fractionation in vacuum (2 mm) gave: 1) b.p. 78-130°, n_D^{20} 1.5480, 2.5 g; 2) b.p. 130-142°, n_D^{20} 1.5298, 0.8 g; 3) b.p. 142-146°, n_D^{20} 1.5388, 14.5 g.

The third fraction – the hydroxyester (XXXVII) – is a pale-green, viscous liquid with a faint amine odor, boiling after redistillation at 143-145° (2 mm), n_D^{20} 1.5388.

Found %: C 68.30, 68.22; H 7.80, 7.75. $C_{15}H_{21}O_3N$. Calculated %: C 68.44; H 7.99.

1,2-Dimethyl-4-hydroxy-4-carbomethoxydecahydroquinoline (XLII). Saponification of 12 g 1,2-dimethyl--4-hydroxy-4-cyanodecahydroquinoline (XXXVIII) (m.p. 119-120°) followed by esterification of the resultant hydroxy acid (XL) with methanol gave 10.1 g oily product which was distilled in vacuum (2.5 mm): 1) b.p. 109-129°, n_D^{20} 1.5007, 3.5 g; 2) b.p. 129-140°, n_D^{20} 1.5063, 6.4 g.

The 2nd fraction – a very viscous, pale-green oil – soon crystallized completely. The 1st fraction also partly crystallized when kept. After two recrystallizations from a mixture of gasoline and acetone, the hydroxyester (XLII) forms lustrous plates melting at 73-74°.

Found %: N 5.80, 5.89. $C_{13}H_{23}O_3N$. Calculated%: N 5.80.

Hydrochloride: m.p. (after two recrystallizations from anhydrous alcohol) 182-183° (with decomp.).

Found %: N 5.16, 5.21. $C_{13}H_{24}O_3NCl$. Calculated %: N 5.05.

1,2-Dimethyl-4-hydroxy-4-carbomethoxyperhydropyridine (XLIII). Esterification with methyl alcohol of the hydroxy acid (XXXIX), obtained by saponification of the cyanohydrin of 1,2-dimethyl-4-hydroxy-4-ketoperhydropyridine (XXXIX) (m.p. 135-136°), gave 9.6 g of hydroxyester (XLIII); this was recrystallized from acetone and formed snow-white plates or prisms grouped in rosettes, m.p. 113-114°.

Found %: N 6.28, 6.22. $C_{12}H_{21}O_3N$. Calculated %: N 6.16.

Methiodide: m.p. 189-190° (decomp.) after recrystallization from anhydrous alcohol.

Found %: N 3.62, 3.67. $C_{13}H_{24}O_3NI$. Calculated %: N 3.90.

2,2-Dimethyl-4-carbomethoxytetrahydropyran-4-ol (XLVIII). a) 12.6 g 2,2-dimethyl-4-hydroxytetrahydropyran-4-carboxylic acid (XXV) (m.p. 109-110°) was esterified with methyl alcohol in the usual manner. The excess methyl alcohol was removed and the residue worked up in the usual way to give 7.4 g hydroxyester (XLVIII) as a viscous, colorless liquid with a characteristic pleasant odor.

B.p. 73-74° (2 mm), n_D^{20} 1.4665, d_4^{20} 1.1219, MR_D 46.45; Calc. 46.38,

Found %: C 57.43, 57.26; H 8.33, 8.62. $C_9H_{16}O_4$. Calculated %: C 57.44; H 8.51.

b) 5 g of the cyanohydrin of 2,2-dimethyltetrahydropyran-4-one (XXIII) (m.p. 84-85°) was mixed with 5 ml anhydrous methanol and converted into the hydrochloride of the iminoether (LIV) by passage of dry hydrogen chloride while cooling with ice and salt. The viscous syrup rapidly crystallized on cooling. The crystals were dissolved in 50 ml iced water; the solution was shaken for 30 minutes with saturated potassium carbonate solution and extracted 5 times with ether. The combined ether extracts were dried with sodium sulfate. The ether was

driven off to leave 4.6 g hydroxyester (XLVIII) with b.p. 74-76° (2.5 mm); n_D^{20} 1.4659.

<u>2,2-Dimethyl-4-carbomethoxytetrahydro-4-thiopyran-4-ol (XLIX).</u> a) 22 g 2,2-dimethyl-4-hydroxytetrahydrothiopyran-4-carboxylic acid (XXVI) (m.p. 76-76.5°) was esterified with methyl alcohol by the usual procedure. After removal of excess methanol, the product was worked up in the usual manner to give 17.2 g of oily substance with a characteristic sulfurous odor. The following fractions were obtained by vacuum distillation (3.5 mm): 1) b.p. to 109°, n_D^{20} 1.4995, 1.5 g; 2) b.p. 109-110°, n_D^{20} 1.5083, 13.6 g; 3) b.p. 110-113°, n_D^{20} 1.5192, 1.1 g.

The 2nd fraction – the hydroxy ester (XLIX) – is a pale-green, viscous liquid.

B. p. 109-110° (3.5 mm), n_D^{20} 1.5082, d_4^{20} 1.1483, MR_D 53.05; Calc. 52.68.

Found %: C 53.52, 53.90; H 7.72, 7.79; S 15.71, 15.68. $C_9H_{16}O_3S$. Calculated %: C 52.94; H 7.84; S 15.67.

b)9.8 gcyanohydrin of 2,2-dimethyltetrahydrothiopyran-4-ol (XXIV) (m.p. 76-76.5°) was mixed with 10 ml anhydrous methanol and converted into the hydrochloride of the iminoether (LV) by passage of dry hydrogen chloride as described above. Hydrolysis and working up in the usual manner gave 6.4 g hydroxyester (XLIX) with b.p. 107-109° (3 mm), n_D^{20} 1.5079.

SUMMARY

Cyanohydrins of γ-piperidones are easily transformed into the corresponding 4-carbalkoxy-4-piperidols which are important intermediates for the synthesis of anesthetics of the type of α-eucaine.

These transformations were realized both by saponification of the cyanohydrins and subsequent esterification of the α-hydroxy acids with various alcohols (yields of 50 to 90%) and by alcoholysis. Alcoholysis of cyanohydrins of γ-piperidones in presence of concentrated sulfuric acid or of hydrogen chloride (followed by hydrolysis of the resultant iminomethyl ethers of the piperidinic α-hydroxy acids) enables preparation of hydroxyesters in 75-80% yield in practice in a single operation.

In both cases, however, alcoholysis of the cyanohydrins is accompanied by formation of amides of the corresponding α-hydroxy acids which are sometimes the main products of reaction in place of the expected hydroxyesters.

Some cyanohydrins of γ-piperidones are capable to a limited extent of entering into the alcoholysis reaction in presence of acids due to the insolubility in alcohols of the salts of these cyanohydrins. Cyanohydrins of tetrahydro-γ-pyrones and tetrahydro-γ-thiopyrones readily undergo alcoholysis and are smoothly transformed into the corresponding hydroxyesters.

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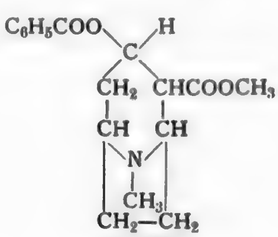
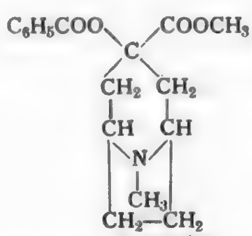
47. SYNTHETIC ANESTHETIC SUBSTANCES
X. ESTERS OF 1,2,5-TRIMETHYL-4-CARBALKOXY-4-PIPERIDOLS. NEW SYNTHETIC ANALOGS OF α-COCAINE AND α-EUCAINE

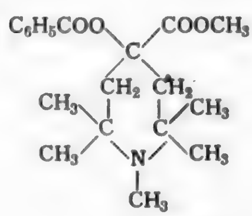
I. N. Nazarov, B. V. Unkovsky and Yu. B. Volkenshtein

Among the numerous papers on the synthesis of anesthetic substances, very special interest is attached to those in the field of piperidinic analogs of cocaine; the latter approach more closely than any other synthetic anesthetics to the structure of the natural alkaloid. At an early date [1] a valuable preparation of this class was discovered in the shape of α-eucaine [1]; the latter possesses the high anesthetic activity of cocaine but is free from the undesirable secondary effect of the latter, and it has found fairly wide application in clinical practice. This preparation, however, possessed an irritant action on the tissues and was gradually displaced by novocaine and its structural analogs of simpler structure and greater ease of manufacture. These developments led to nearly complete neglect by investigators of compounds similar in structure to eucaine and α-cocaine. Novocaine is now the most widely used anesthetic and has low toxicity, but its anesthetic activity is relatively low. This characteristic limits its application in a number of cases. Powerful modern anesthetics – dicaine (pantocaine) and sovcaine – are 10-12 times more active than novocaine but correspondingly more toxic than novocaine, so that their utilization in surgery often leads to undesirable complications. Many synthetic anesthetic substances combine high anesthetic activity with irritant action on the tissues or painful effects. Consequently, the problem of local anesthesia has not yet been satisfactorily solved in spite of the existence of a large number of synthetic substituents for cocaine.

In the preceding communication [2] we described the synthesis of diverse 4-carbalkoxy-4-piperidols which can serve as starting substances for the preparation of new anesthetics since the esters of these piperidols are similar in structure to α-eucaine [1] and α-cocaine [3].


cocaine

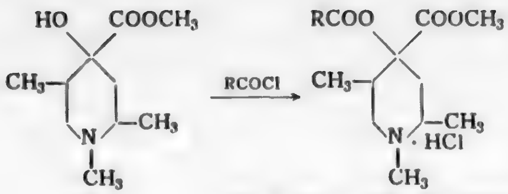

α-cocaine


α-eucaine

This type of anesthetic substance, as mentioned above, had been scarcely investigated until now, mainly due to the difficult accessibility and the complexity of synthesis of γ-piperidones. Systematic study of new analogs of α-eucaine offers great possibilities for the discovery of highly active anesthetics and for establishment of the relation between their chemical structure and physiological activity.

In the present paper we describe the synthesis of a series of esters of 1,2,5-trimethyl-4-carbalkoxy-4-piperidols for the purpose of study of their anesthetic activity.

Reaction of 1,2,5-trimethyl-4-carbomethoxy-4-piperidol (I) with acid chlorides (mainly aromatic and fatty-aromatic) gave a series of esters which enable us to follow in broad outline the relation between their anesthetic activity and the character of the acyl (or aryl) residue:



(I)

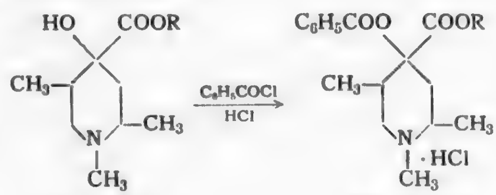
(II) R = CH_3 (III) R = C_2H_5 (IV) R = C_6H_5 (V) R = $C_6H_5CH_2$ (VI) R = $C_6H_5CH{=}CH$ (VII) R = $C_6H_5CH_2CH_2$ (VIII) R = $C_6H_5OCH_2$ (IX) R = $C_6H_4NO_2$ (X) R = $C_6H_4NH_2$

Esterification was effected by heating the hydroxyester (I) with acid chloride on a boiling water bath for 4-5 or $1^1/_2$-2 hours at 120-130°. The hydrochlorides of the following esters of 1,2,5-trimethyl-4-carbomethoxy--4-piperidol (I) were prepared in this way: acetate (II) (yield (99%); propionate (III) (yield 89.1%); benzoate (IV) (yield 88.3%); phenylacetate (V) (yield 75.6%); cinnamate (VI) (yield 62%); β-phenylpropionate (VII) (yield 73.1%); phenoxyacetate (VIII) (yield 95%); and p-nitrobenzoate (IX) (yield 43%).

The hydrochloride of the p-nitrobenzoate (IX) was readily transformed into the monohydrochloride of the p-aminobenzoate (X) by catalytic hydrogenation over skeletal nickel, while the cinnamate (VI) was similarly transformed into the β-phenylpropionate (VII).

An attempt to esterify the hydroxyester (I) with diphenylacetic, phthalic and acetylmandelic acids was unsuccessful. Reaction of the acid chlorides of these acids both with the base and with the hydrochloride of 1,2,5-trimethyl-4-carbomethoxy-4-piperidol (I) at 130-140° gave, in place of the expected esters, products of unclarified structure. On conversion to the free base the latter appeared as deeply colored oils readily soluble in water, acetone and methanol but insoluble in ether. At lower temperatures of attempted esterification the hydroxyester (I) was recovered unchanged.

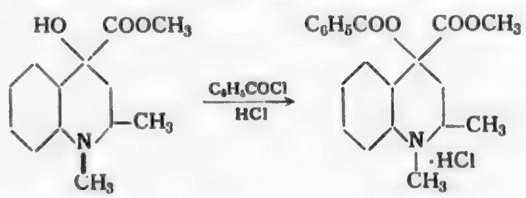
With the objective of establishing the influence of the alcoholic radical of the carbalkoxyl group on the anesthetic activity and toxicity of the preparations, a series of benzoates of 1,2,5-trimethyl-4-carbalkoxy-4-piperidols (XV-XVIII) was prepared (yields 80-90%):



(XI) R = C_2H_5 (XII) R = C_3H_7 (XIII) R = C_4H_9 (XIV) R = iso C_5H_{11}

(XV) R = C_2H_5 (XVI) R = C_3H_7 (XVII) R = C_4H_9 (XVIII) R = iso C_5H_{11}

We also reacted benzoyl chloride with 1,2-dimethyl-4-hydroxy-4-carbomethoxydecahydroquinoline (XIX) and thereby obtained the corresponding bicyclic benzoate (XX) in the form of the hydrochloride (91% yield):

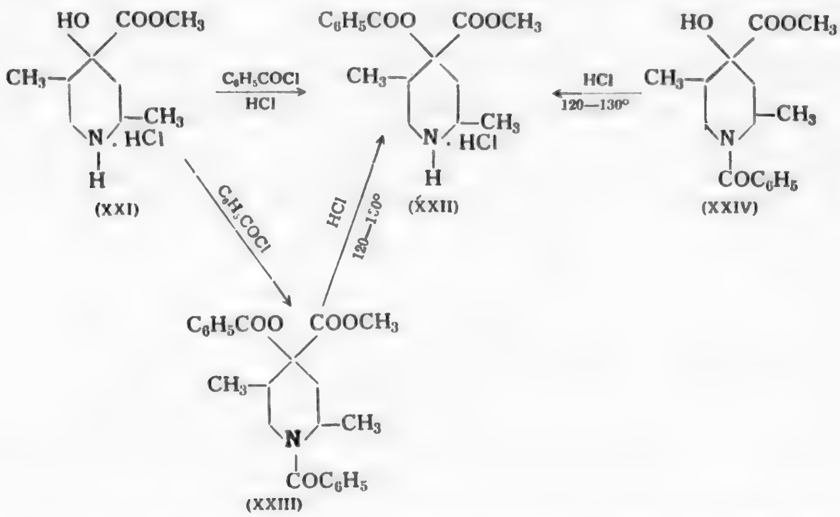


(XIX) (XX)

Difficulties were encountered at the start in the synthesis of the benzoate of 2,5-dimethyl-4-carbomethoxy-4-piperidol (XXII) due to the unexpected facility of arylation of the unsubstituted amino group of the hydro-

chloride of this compound.

Whereas the hydrochloride of 2,2,6-trimethyl-4-piperidol is smoothly benzoylated at 140-150° with formation of the hydrochloride of the corresponding benzoate (the known preparation β-eucaine [4]), the hydrochloride of the hydroxyester (XXI) is quantitatively transformed under these conditions into the dibenzoyl derivative (ester-amide) (XXIII).



The benzoate (XXII) was easily obtained in the form of the hydrochloride in 90% yield by heating the hydrochloride of the hydroxyester (XXI) with benzoyl chloride previously saturated with dry hydrogen chloride.

The base of the hydroxyester (XXI) is likewise readily esterified with an equimolar amount of benzoyl chloride. Heating of the initially formed N-benzoyl derivative (amide) (XXIV) for 2 hours at 120-130° with simultaneous passage into the reaction mixture of dry hydrogen chloride leads, as a result of the N→O acyl rearrangement [5-9], to quantitative transformation into the hydrochloride of the benzoate (XXII).

The ester-amide (XXIII), prepared by benzoylation of the hydroxyester (XXI) in a neutral medium at 130-140°, can also be readily transformed into the hydrochloride of the benzoate (XXII) by heating at 120-130° for 2 hours with simultaneous introduction of a stream of dry hydrogen chloride which brings about deacylation of the secondary amino group.

The esters of 1,2,5-trimethyl-4-carbomethoxy-4-piperidol (IV-X) that we synthesized were tested for their activity in surface, infiltration and radical anesthesia. Pronounced activity was observed. The anesthetic activity of the cinnamate (VI), β-phenylpropionate (VII) and phenoxyacetate (VIII) is considerably higher than that of novocaine and cocaine and approximates to that of one of the strongest of modern anesthetics (dicaine) while their toxicity is several times lower. These compounds may be of practical interest as substitutes for the highly toxic dicaine which is widely used at the present time in clinical practice.*

EXPERIMENTAL

Acetate of 1,2,5-trimethyl-4-carbomethoxy-4-piperidol (II). To 5 g of 1,2,5-trimethyl-4-carbomethoxy-4-piperidol (I) (m.p. 117-118°) [2] was added 2.5 ml acetyl chloride (50% excess of acid chloride). The reaction commenced at once with considerable heat development and violent evolution of hydrogen chloride for several minutes. The mixture was heated 30 minutes on a boiling water bath; the solidified reaction mass was ground to powder under absolute ether and washed with fresh portions of ether until the odor of acetyl chloride had disappeared. The product was filtered and dried in a vacuum-desiccator. Yield 6.9 g of the hydrochloride of the

* The pharmacological investigations were carried out by Professor M. D. Mashkovsky and his co-workers in the All-Union S. Ordzhonikidze Institute of Pharmaceutical Chemical Research. The authors accord their thanks.

acetate of 1,2,5-trimethyl-4-carbomethoxy-4-piperidol (II), which after two recrystallizations from acetone melted at 173° (with evolution of gas).

Found %: Cl 12.51. $C_{12}H_{22}O_4NCl$. Calculated %: Cl 12.69.

The base, isolated from the hydrochloride in the usual manner, was recrystallized from gasoline and formed well-developed, lustrous needles, m.p. 87-88°.

Found %: N 5.56, 5.52. $C_{12}H_{21}O_4N$. Calculated %: N 5.77.

Propionate of 1,2,5-trimethyl-4-carbomethoxy-4-piperidol (III). To 5 g of hydroxyester (I) (m.p. 117-118°) [2] was added 4.3 ml propionyl chloride. The reaction soon commenced with frothing and considerable heat development. The mixture was heated 2 hours on a boiling water bath, after which the solidified product was worked up as in the preceding preparation; it was dissolved in acetone and boiled with activated charcoal. The oil remaining after removal of the acetone was dried in a vacuum-desiccator where it quickly crystallized completely. Yield 6.5 g hydrochloride of the propionate of 1,2,5-trimethyl-4-carbomethoxy-4-piperidol (III), which was recrystallized three times from acetone to give soft needles, forming a fibrous mass on the filter. M. p. 80-81°.

Found %: N 5.07, 4.98. $C_{13}H_{24}O_4NCl$.. Calculated %: N 4.78.

The propionate base is a viscous oil which does not crystallize after prolonged storage.

Benzoate of 1,2,5-trimethyl-4-carbomethoxy-4-piperidol (IV). 5 g of hydroxyester (I) (m.p. 117-118°) was mixed with 10 ml benzoyl chloride and heated 5 hours on a boiling water bath. The mixture soon became homogeneous and darkened appreciably. The excess benzoyl chloride was taken off in vacuum. The viscous residue was quickly transformed into a powder by trituration under absolute ether; it was filtered and dried in a vacuum-desiccator. Yield 7.5 g of the hydrochloride of the benzoate of 1,2,5-trimethyl-4-carbomethoxy-4-piperidol (IV). This was twice reprecipitated with absolute ether from absolute alcohol and then recrystallized from a mixture of acetone and gasoline. The latter step was carried out by adding gasoline dropwise to a hot, concentrated solution of the hydrochloride in acetone until the solution was turbid. Well-formed, hard prisms of the hydrochloride of the benzoate (IV) slowly came down on standing. M.p. 125° (with gas evolution).

Found %: N 4.24, 4.18. $C_{17}H_{24}O_4NCl$. Calculated %: N 4.09.

Phenylacetate of 1,2,5-trimethyl-4-carbomethoxy-4-piperidol (V). To 5 g of hydroxyester (I) (m.p. 117-118°) was added 6 g of phenylacetyl chloride (b.p. 106-107° at 25 mm). The mixture was heated to 120°, and after melting of the hydroxyester it was thoroughly stirred until the solution was homogeneous. Hydrogen chloride came off during the first 10-15 minutes. After heating for 3 hours at 130°, the solidified mass was treated with 50 ml water; phenylacetic acid came down from the acid solution and was extracted with three portions of ether; the aqueous solution was saturated with potassium carbonate and the supernatantoily base was extracted with five portions of ether. The combined ethereal extracts were dried with calcined sodium sulfate. The ether was driven off to leave 6 g of oily base of the phenylacetate of 1,2,5-trimethyl-4-carbomethoxy-4-piperidol (V), which did not crystallize after standing for a long period.

The hydrochloride was obtained by passing dry hydrogen chloride into the ethereal solution of the base; it was then dissolved in anhydrous alcohol and boiled with activated charcoal.

Concentration of the alcoholic solution resulted in separation of stout, transparent, rhombic crystals of the hydrochloride of the phenylacetate (V) which melted at 157-157.5° after three recrystallizations from anhydrous alcohol.

Found %: N 3.99, 4.16. $C_{18}H_{26}O_4NCl$. Calculated %: N 3.94.

Phenoxyacetate of 1,2,5-trimethyl-4-carbomethoxy-4-piperidol (VIII). A mixture of 4.5 g hydroxyester (I) (m.p. 117-118°), 10 ml anhydrous benzene and 4.6 ml phenoxyacetyl chloride (b.p. 139-140° at 30 mm) was heated for 6 hours on a boiling water bath. The crystalline product of the reaction was pulverized, washed with several portions of absolute ether until the odor of the acid chloride had disappeared, filtered, and dried in a vacuum-desiccator. Yield 8 g of the hydrochloride of the phenoxyacetate of 1,2,5-trimethyl-4-carbomethoxy-4-piperidol (VIII), which formed colorless needles with m.p. 174° (decomp.) after 3 recrystallizations from anhydrous alcohol.

Found %: N 4.12, 3.99. $C_{18}H_{26}O_5NCl$. Calculated %: N 3.77.

Cinnamate of 1,2,5-trimethyl-4-carbomethoxy-4-piperidol (VI). To 13.4 g hydroxyester (I) (m.p. 117-118°) was added 14.7 g cinnamyl chloride (b.p. 92-95° at 3 mm). Reaction commenced quickly with considerable heat development and violent evolution of hydrogen chloride. The melted mixture was well stirred and heated for 2 hours at 130-135°. The crystalline product was ground to a fine powder and dissolved in 150 ml water. The separated cinnamic acid was filtered off and the acid filtrate was twice extracted with ether and saturated with potassium carbonate.

In other experiments in which the acidic aqueous solution was extracted with ether, the moderately water-soluble cinnamate of 1,2,5-trimethyl-4-carbomethoxy-4-piperidol (VI) was nearly quantitatively precipitated and was readily purified by recrystallization from anhydrous alcohol.

The upper layer of oil, obtained on saturation of the aqueous solution with potassium carbonate, was extracted six times with ether and the combined ether extracts were dried with calcined sodium sulfate. Removal of the ether left 13.6 g of the oily base of the cinnamate of 1,2,5-trimethyl-4-carbomethoxy-4-piperidol (VI), which quickly crystallized. It was recrystallized 3 times from a mixture of gasoline and alcohol; beautiful rosettes of stout, hard lamellar crystals, m.p. 93-94°.

Found %: N 4.28, 4.38. $C_{19}H_{25}O_4N$. Calculated %: N 4.22.

Hydrochloride: soft, snow-white needles from acetone or anhydrous alcohol; m.p. 166° (with decomp.).

Found %: N 3.89, 3.86; Cl 9.67. $C_{19}H_{26}O_4NCl$. Calculated %: N 3.82; Cl 9.67.

Methiodide: m.p. 215° (after recrystallization from anhydrous alcohol).

Found %: N 2.83, 3.16. $C_{20}H_{28}O_4NI$. Calculated %: N 2.96.

β-Phenylpropionate of 1,2,5-trimethyl-4-carbomethoxy-4-piperidol (VII). a) A solution of 4 g of the hydrochloride of the cinnamate of 1,2,5-trimethyl-4-carbomethoxy-4-piperidol (VI) in 50 ml anhydrous alcohol was placed in a hydrogenation vessel and shaken for 5 hours in a hydrogen atmosphere in presence of skeletal nickel catalyst. After $4^1/_2$ hours 240 ml hydrogen (21°, 746 mm) had been taken up as compared with the theoretical requirement of 245 ml. The catalyst was separated and the alcohol driven off in vacuum. Yield 4 g of crystalline hydrochloride of the β-phenylpropionate (VII); lustrous plates after recrystallization from acetone; m.p. 164° (decomp.).

Found %: N 4.05, 4.04. $C_{19}H_{28}O_4NCl$. Calculated %: N 3.79.

Methiodide: m.p. 146-147° after two recrystallizations from anhydrous alcohol.

Found %: N 3.07, 3.22. $C_{20}H_{30}O_4NI$. Calculated %: N 2.94.

b) To 11.3 g of hydroxyester (I) was added 14 g of β-phenylpropionyl (hydrocinnamyl) chloride (b.p. 83-84° at 3 mm). Considerable heat was developed on stirring and hydrogen chloride came off. The reaction mass was heated to 120° and thoroughly stirred after the hydroxyester had melted, after which the heating was continued for another 2 hours at 130-140°. The solidified mass was crushed to powder and dissolved in 150 ml water. Hydrocinnamic acid came down and was removed by three extractions of the acid solution with ether. The solution was saturated with potassium carbonate, the supernatant oily base was extracted with five portions of ether, and the ethereal extracts were combined and dried with calcined sodium sulfate. After removal of the ether, the oily residue did not crystallize on long standing. Yield 13.5 g of the β-phenylpropionate (VII) base.

Hydrochloride: m. p. 164° after two reprecipitations with absolute ether from acetone followed by recrystallization from acetone.

Found %: N 3.94, 4.08. $C_{19}H_{28}O_4NCl$. Calculated %: N 3.79.

Methiodide: m.p. 146-147° after reprecipitation from alcohol with absolute ether and recrystallization from alcohol. A mixed test with a specimen of methiodide from the preceding experiment did not give a depression.

p-Nitrobenzoate of 1,2,5-trimethyl-4-carbomethoxy-4-piperidol (IX). A mixture of 10 g hydroxyester (I) and 14 g p-nitrobenzoyl chloride (m.p. 74-75°) was heated to 120°, thoroughly stirred and further heated for $1^1/_2$ hours at 130-140°. The solid reaction mass was crushed to powder and treated with 150 ml water. The

p-nitrobenzoic acid was filtered off and the aqueous solution neutralized with potassium carbonate; this quickly brought down the yellow, crystalline base which was filtered and dried in a vacuum-desiccator. Yield 7 g of the p-nitrobenzoate (IX); yellow crystals with m.p. 165-165.5° after two recrystallizations from acetone.

The filtrate was saturated with potassium carbonate and extracted with three portions of ether; the ethereal extracts were combined and dried with calcined sodium sulfate. Removal of the ether left a further 0.5 g of product. The total yield of nitrobenzoate (IX) in this experiment was 7.5 g.

Found %: N 8.25, 8.09. $C_{17}H_{22}O_6N_2$. Calculated %: N 8.00.

Hydrochloride: lustrous, hard needles with m.p. 178° (decomp.) after recrystallization from anhydrous alcohol.

Found %: N 7.10, 7.31. $C_{17}H_{23}O_6N_2Cl$. Calculated %: N 7.26.

p-Aminobenzoate of 1,2,5-trimethyl-4-carbomethoxy-4-piperidol (X). 1.5 g of the hydrochloride of the p-nitrobenzoate (IX) (m.p. 178° with decomp.) was dissolved in the cold in 50 ml anhydrous alcohol and placed in a hydrogenation vessel. The solution was shaken in a hydrogen atmosphere in presence of skeletal nickel catalyst for 7 hours. 420 ml hydrogen (17°, 743 mm) was absorbed as against the theoretical requirement of 430 ml. The solution was filtered from catalyst, the alcohol was distilled off in vacuum and the yellow, oily residue crystallized on drying in a vacuum-desiccator. Yield 2 g (86.7%) of the monohydrochloride of the p-aminobenzoate (X).

After 3 recrystallizations from anhydrous alcohol, the product formed pale-yellow rosettes melting at 196° (decomp.).

Found %: N 7.64, 7.59. $C_{17}H_{25}O_4N_2Cl$. Calculated %: N 7.86.

Dibenzoyl derivative of 2,5-dimethyl-4-carbomethoxy-4-piperidol (XXIII). 5 g of the hydrochloride of 2,5-dimethyl-4-carbomethoxy-4-piperidol (XXI) with m.p. 212° (decomp.) [2] was mixed with 10 ml benzoyl chloride; the suspension was heated to 115° when the hydrochloride began to dissolve in the benzoyl chloride with much evolution of hydrogen chloride. The mixture rapidly became homogeneous and acquired a cherry-red color. Heating was continued for another $1^1/_2$ hours until hydrogen chloride ceased to come off. The excess benzoyl chloride was removed in vacuum. The viscous residue was treated with absolute ether and dissolved in the latter completely. The extract was shaken for a long time with saturated sodium carbonate solution and then dried with calcined sodium sulfate. The dark greasy substance remaining after removal of the ether decomposed when distillation in vacuum (2 mm) was attempted. The product dissolves readily in ether, alcohol and acetone; it is insoluble in water and inert towards acids and alkalies (confirming its neutral amide character).

Numerous attempts to purify the product were unsuccessful; it is evidently the N,O-dibenzoyl derivative of 2,5-dimethyl-4-carbomethoxy-4-piperidol (XXIII).

Benzoate of 2,5-dimethyl-4-carbomethoxy-4-piperidol (XXII). a) 5 g of the hydrochloride of 2,5-dimethyl-4-carbomethoxy-4-piperidol (XXII) with m.p. 212 (decomp.) was mixed with 5 ml benzoyl chloride previously saturated with hydrogen chloride, and the mixture was heated for 2 hours at 130-140°. The hydrochloride rapidly went into solution with evolution of gas bubbles, and the mixture became homogeneous. The cooled product was crushed to powder under absolute ether, and after 3 changes of ether the slightly hygroscopic hydrochloride was filtered off and dried in a vacuum-desiccator. Yield 6.6 g of the hydrochloride of the benzoate (XXII) which formed soft needles with m.p. 186-187° (decomp.) after two recrystallizations from acetone.

Found %: N 4.13, 4.21. $C_{16}H_{22}O_4NCl$. Calculated %: N 4.28.

b) 5 g of the base of 2,5-dimethyl-4-carbomethoxy-4-piperidol (XXI) (m.p. 107-108°) was mixed with 3.7 g benzoyl chloride (equimolar amount) and heated 2 hours at 130-140° with continuous introduction of dry hydrogen chloride. Addition of benzoyl chloride caused the temperature to rise and hydrogen chloride was evolved. After treatment of the product with absolute ether until the odor of benzoyl chloride had completely vanished, the hydrochloride was triturated to powder under absolute ether, filtered and dried in a vacuum-desiccator. Yield 7.8 g hydrochloride of the benzoate (XXII). This was reprecipitated from alcohol with absolute ether and twice recrystallized from acetone; m.p. 187° (decomp.).

c) 3 g of the unpurified dibenzoyl derivative (XXIII) described above was heated at 130-140° for 2 hours while dry hydrogen chloride was introduced. The cooled product (hydrochloride) was pulverized under absolute ether and then boiled with activated charcoal in anhydrous alcohol. After removal of the alcohol the product was recrystallized from acetone. Yield 2.2 g of the hydrochloride of the benzoate (XXII) with m.p. 185-187° (decomp.); no depression in admixture with specimens from the preceding experiments.

Benzoate of 1,2,5-trimethyl-4-carboethoxy-4-piperidol (XV). 8 g of 1,2,5-trimethyl-4-carboethoxy-4-piperidol (XI) (m.p. 55-56°) [2] was mixed with 10 ml benzoyl chloride which had been previously saturated with hydrogen chloride, and the mixture was heated 7 hours on a boiling water bath. The reaction mass was dissolved in 50 ml water, the acid solution was extracted four times with ether and saturated with potassium carbonate; the oily base separated out and was extracted four times with ether. The combined ethereal extracts were dried with calcined sodium sulfate and the ether was driven off to leave 10.45 g of the base of the benzoate (XV) which did not crystallize when kept for several days. The base was converted to the hydrochloride which became moist on the filter. After drying in a vacuum-desiccator, it was dissolved in acetone and boiled with activated charcoal. The residue after removal of the acetone was pulverized under absolute ether and dissolved in the minimum amount of anhydrous alcohol. Careful dropwise addition of absolute ether until cloudy led to separation from the solution of a snow-white, fibrous mass which gradually crystallized into fine rosettes. After recrystallization from alcohol the hydrochloride of the benzoate (XV) had m.p. 101-103°.

Found %: N 3.91, 3.69. $C_{18}H_{26}O_4NCl$. Calculated %: N 3.94.

Benzoate of 1,2,5-trimethyl-4-carbopropoxy-4-piperidol (XVI). 4.7 g of 1,2,5-trimethyl-4-carbopropoxy-4-piperidol (XII) (m.p. 51-52°) [2] was reacted with 5 g benzoyl chloride by the method described above to give 5.6 g of the oily base of the benzoate (XVI) which did not crystallize after prolonged standing. Hydrogen chloride was passed into the solution of the base in absolute ether to form the hydrochloride. The latter turned moist on the filter. It was boiled with activated charcoal in acetone and then converted to the crystalline state by two reprecipitations from anhydrous alcohol with absolute ether. The hydrochloride of the benzoate (XVI) melts at 131-132° (decomp.).

Found %: N 3.61, 3.49. $C_{19}H_{28}O_4NCl$. Calculated %: N 3.79.

Benzoate of 1,2,5-trimethyl-4-carbobutoxy-4-piperidol (XVII). 8 g of 1,2,5-trimethyl-4-carbobutoxy-4-piperidol (XIII) (m.p. 49-50°) [2] was reacted with 8 ml benzoyl chloride by the above-described method to give 11.75 g of the oily base of the benzoate (XIII) which did not crystallize when kept for several days. The hydrochloride of the base (hygroscopic in the air) was dried in a vacuum-desiccator and dissolved in acetone. The solution was boiled with activated charcoal. After removal of the acetone, the hydrochloride was crushed to powder under absolute ether, dissolved in the minimum amount of anhydrous alcohol and precipitated by dropwise addition of absolute ether until the solution was turbid. The separated oil rapidly crystallized. By addition of fresh portions of ether it was possible to convert the whole of the product into stout, lustrous rosettes. M. p. 158-160° after recrystallization from anhydrous alcohol.

Found %: N 3.37, 3.51. $C_{20}H_{30}O_4NCl$. Calculated %: 3.65.

Benzoate of 1,2,5-trimethyl-4-carboisoamyloxy-4-piperidol (XVIII). Reaction of 8.5 g of 1,2,5- triethyl-4-carboisoamyloxy-4-piperidol (XIV) (b.p. 118-120° at 3.5 mm) [2] with 15 ml benzoyl chloride, as described for preparation of the benzoate (XV), led to isolation of 9.33 g of oily base of the benzoate (XVIII) which was converted to the hydrochloride. The white, flocculent precipitate (hygroscopic) was dried in a vacuum-desiccator and recrystallized from acetone. The hydrochloride of the benzoate (XVIII) was twice recrystallized and formed lustrous needles with m.p. 151-152°.

Found %: N 3.55, 3.44. $C_{21}H_{32}O_4NCl$. Calculated %: N 3.54.

Benzoate of 1,2-dimethyl-4-hydroxy-4-carbomethoxydecahydroquinoline (XX). Reaction of 8 g of 1,2-dimethyl-4-hydroxy-4-carbomethoxydecahydroquinoline (XIX) (m.p. 82-85°) [2] with 15 ml benzoyl chloride under the conditions described above gave 10.25 g of the oily base of the benzoate (XX) which did not crystallize after prolonged storage. The base was converted to the hydrochloride (hygroscopic during filtration), dissolved in anhydrous alcohol and boiled with activated charcoal. After removal of the alcohol, the residue was triturated to a powder under absolute ether and dissolved in the minimum amount of anhydrous alcohol. Dropwise addition of absolute ether until the solution was turbid led to slow formation of stout rosettes. After recrystallization from

anhydrous alcohol the hydrochloride of the benzoate (XX) melted at 189-190° (decomp.).

Found %: N 3.77, 3.60. $C_{20}H_{23}O_4NCl$. Calculated %: N 3.67.

SUMMARY

Reaction of 1,2,5-trimethyl-4-carbalkoxy-4-piperidols (I), (XI), and (XII), 2,5-dimethyl-4-carbomethoxy-4-piperidol (XXI) and 1,2-dimethyl-4-hydroxy-4-carbomethoxydecahydroquinoline (XIX) with chlorides of aromatic and fatty-aromatic acids led to preparation of 15 esters similar in structure to α-cocaine and α-eucaine.

The esters of 1,2,5-trimethyl-4-carbomethoxy-4-piperidol (IV-X) exhibit activity in surface, infiltration and radical anesthesia. The cinnamate (VI), phenylpropionate (VII) and phenoxyacetate (VIII) resemble dicaine in anesthetic activity but are several times less toxic.

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HETEROCYCLIC COMPOUNDS

48. 1-CARBALKOXYALKYL-2,5-DIMETHYL-4-PIPERIDONES

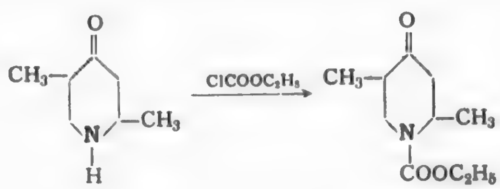
I. N. Nazarov, T. V. Sheremeteva and R. I. Kruglikova

The synthesis of 4-piperidones with various substituents in the piperidine ring has formed part of a project for the synthesis of physiologically active compounds of the piperidine series. In the present communication we describe the synthesis of 2,5-dimethyl-4-piperidones substituted at the nitrogen by residues of carboxylic acids, their esters and some other derivatives.

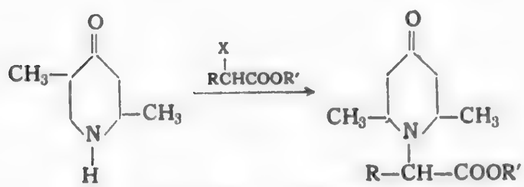
Up to now the sole known representative in the series of 1-carbalkoxyalkyl-4-piperidones was the 1-carbethoxymethyl-2,6-dimethyl-3-carbomethoxy-4-piperidone prepared by Mannich [1]. The difficulty of preparation of this type of compound was mainly due to the unavailability of 4-piperidones not substituted at the nitrogen and containing various substituents in the ring. After I. N. Nazarov and co-workers had developed a simple and general method of preparation of such 4-piperidones by reaction of divinyl ketones [2] with ammonia or ammonium acetate [3], various 4-piperidonecarboxylic acids and their derivatives became readily accessible compounds.

We prepared 2,5-dimethyl-4-piperidonecarboxylic acids and their derivatives by three routes: 1) by reaction of 2,5-dimethyl-4-piperidone with α-halo-substituted acids and their esters; 2) by reaction of propenyl-isopropenyl ketone and the corresponding methoxy ketones with esters of α-amino acids; 3) by addition of acrylic acid derivatives to 2,5-dimethyl-4-piperidone.

The reaction of 2,5-dimethyl-4-piperidone with esters of α-halo-substituted acids is closely analogous to the reaction of piperidine with the same compounds [4] but goes less energetically, and a much larger proportion of the product is lost due to resinification. 2,5-Dimethyl-4-piperidone was reacted with the ethyl esters of chlorocarbonic, chloro- and bromoacetic, α-bromopropionic and α-bromobutyric acids as well as with bromoacetic acid.



(I)



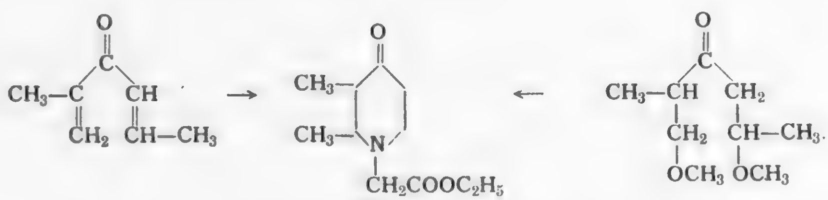
(II) $R = H$, $R' = C_2H_5$,
(III) $R = CH_3$, $R' = C_2H_5$,
(IV) $R = C_2H_5$, $R' = C_2H_5$,
(V) $R = H$, $R' = H$.

Just as in the case of piperidine, one half of the quantity of piperidone taken enters into reaction, the other half being bound in the form of the hydrochloride or hydrobromide by the hydrogen halide formed. The intensity of the reaction decreases with increasing size of the acid chain, and the yield of substituted piperidine falls off in the same order. Yields of products (in %): (I) 78; (II) 83; (III) 60; (IV) 36; (V) 86.

In practice 2,5-dimethyl-4-piperidone can scarcely be said to react with the ethyl ester of α-bromoisovaleric acid.

The conditions of performance of the reaction were studied most closely in the case of preparation of 1-carboethoxymethyl-2,5-dimethyl-4-piperidone (II). It was established that the reaction goes in accordance with the above equation on taking equimolar amounts of 2,5-dimethyl-4-piperidone and ethyl bromoacetate, and half of the ethyl bromoacetate taken into the reaction is recovered unchanged. The reaction was also carried out in presence of a base that might have been capable of binding the hydrogen halide released. Pyridine was selected for this purpose, but even then the reaction followed the mechanism indicated above. The yield obtained when the reaction was performed with ethyl chloroacetate was better than with ethyl bromoacetate (83.5% against 77%) because resinification was reduced.

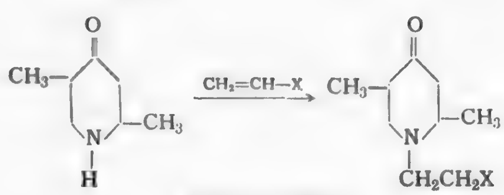
Just as N-alkyl-substituted 2,5-dimethyl-4-piperidones are obtained by cyclization of propenyl-isopropenyl ketone and the corresponding methoxy ketones with primary amines, so was 1-carboethoxymethyl-2,5-dimethyl-4-piperidone (II) obtained by us by reaction of propenyl-isopropenyl ketone and corresponding mono- and dimethoxy ketones with the ethyl ester of glycine.



(II)

The yield was 30% on the ketone taken and 73% on the ketone entering into reaction.

Derivatives of β-(4-piperidone)-carboxylic acids were obtained by reaction of 2,5-dimethyl-4-piperidone with methyl acrylate, acrylonitrile and acrolein.



(VI) $X = COOCH_3$,
(VII) $X = CN$,
(VIII) $X = C{<}^{O}_{H}$.

1-β-Carbomethoxyethyl-2,5-dimethyl-4-piperidone (VI) and 1-β-cyanoethyl-2,5-dimethyl-4-piperidone (VII) were prepared in yields of 96 and 50% (respectively) by heating mixtures of methyl acrylate and acrylonitrile with 2,5-dimethyl-4-piperidone. The reaction of 2,5-dimethyl-4-piperidone with acrolein was conducted in a stream of nitrogen and in presence of an inhibitor (hydroquinone) to suppress polymerization (yield 22.5%).

EXPERIMENTAL

2,5-Dimethyl-4-piperidone [3]. To a solution of 89 g ammonium acetate in 125 ml water was added 100 g of a mixture of propenyl-isopropenyl ketone and corresponding mono- and dimethoxy ketones (b.p. 68-88° at 12 mm) [2], and 275 ml methanol was then gradually run in until a homogeneous solution was formed. The mixture was heated 6 hours at 80°, after which 205 ml methanol was taken off in a low vacuum. The

residue was treated with ether to remove unreacted methoxy ketones, and the piperidone acetate was decomposed with solid potassium hydroxide while cooling with iced water. The separated piperidone was extracted several times with ether, dried with sodium sulfate and fractionally distilled in vacuum. Yield 32.5 g (40%) of 2,5-dimethyl-4-piperidone with b.p. 77-79° (8 mm), n^{20}_{D} 1.4658. The same yield of piperidone was obtained when the reaction was conducted in an aqueous medium with energetic stirring and heating of the mixture of aqueous solution of ammonium acetate and methoxy ketones until the layer of methoxy ketones had disappeared.

1-Carboethoxy-2,5-dimethyl-4-piperidone (I). To 22 g of 2,5-dimethyl-4-piperidone, stirred and cooled with iced water, was added 9.35 g ethyl chlorocarbonate in small portions. Much heat was released and crystals of the hydrochloride of the original 2,5-dimethyl-4-piperidone began to come down after 15 minutes. After standing for 24 hours at room temperature, 10 ml water was added to the completely crystallized mixture; the product was extracted with ether and dried with sodium sulfate. The ether was driven off and the residue distilled in vacuum to give 13.5% (78% reckoned on the ethyl chlorocarbonate) of 1-carboethoxy-2,5-dimethyl-4-piperidone (I).

B. p. 112-114° (3 mm), n^{20}_{D} 1.4692, d^{20}_{4} 1.068, MR 51.97; Calc. 51.68.

Found %: N 7.32, 7.40. $C_{10}H_{15}ON$. Calculated %: N 7.03.

1-Carboethoxy-2,5-dimethyl-4-piperidone is a colorless, mobile liquid, turning faint-yellow on standing; substantially insoluble in water, readily soluble in ether, acetone, alcohol and dioxane. The aqueous layer was treated with potassium hydroxide and extracted with ether to give 8.8 g of the original 2,5-dimethyl-4-piperidone with b.p. 80-84° (8 mm).

1-Carboethoxymethyl-2,5-dimethyl-4-piperidone (II). a) To 23.3 g ethyl chloroacetate was slowly added 50 g 2,5-dimethyl-4-piperidone. The mass crystallized after standing for 2 days at room temperature. The reaction was completed by heating the product at 60° for 10 hours. It was then dissolved in 40 ml water, extracted with ether (3 lots of 20 ml each), dried with sodium sulfate and fractionated in vacuum. Yield 35.1 g (83.5%), reckoned on the ethyl chloroacetate) of 1-carboethoxymethyl-2,5-dimethyl-4-piperidone (II).

B.p. 114-116° (2 mm), n^{20}_{D} 1.4602.

From the aqueous layer was recovered 21.7 g of the original 2,5-dimethyl-4-piperidone.

b) A mixture of 17 g ethyl bromoacetate and 25.8 g 2,5-dimethyl-4-piperidone was stood for 48 hours at room temperature and then heated for 3 hours at 60°. The mixture was worked up in the usual manner and gave 16.55 g (77% reckoned on the ethyl bromoacetate) of 1-carboethoxymethyl-2,5-dimethyl-4-piperidone (II) with b.p. 114-117° (2 mm); n^{20}_{D} 1.4591. 9 g of the original 2,5-dimethyl-4-piperidone was recovered from the aqueous layer.

Performance of the reaction of 2,5-dimethyl-4-piperidone with ethyl bromo- and chloroacetates in solution in dioxane or pyridine under the same conditions resulted in a yield of 1-carboethoxymethyl-2,5-dimethyl-4-piperidone of only 60-70%.

c) A mixture of 18.1 g ethyl glycinate (b.p. 40-42° at 7 mm) and 28 g propenyl-isopropenyl ketone and its corresponding mono- and dimethoxy ketones (b.p. 50-80° at 10 mm) [2] was heated on a water bath at 75° for 8 hours. Fractional distillation in vacuum gave 12 g of 1-carboethoxymethyl-2,5-dimethyl-4-piperidone with b.p. 122-124° (3 mm). In addition the experiment gave 2.5 g of unreacted ethyl glycinate and 17.6 g of the original methoxy ketones. The yield was 30% on the methoxy ketones taken and 78% on the methoxy ketones reacted.

d) A mixture of 19 g ethyl glycinate and 35 g propenyl-isopropenyl ketone and the corresponding methoxy ketones was stood for 48 hours at room temperature and then heated for 11 hours at 85-90°. The product was worked up in the usual manner to give 18.5 g of 1-carboethoxymethyl-2,5-dimethyl-4-piperidone with b.p. 111-113° (1.5 mm). Yield 47% on the ketone taken and 70% on the ketone entering into reaction.

1-Carboethoxymethyl-2,5-dimethyl-4-piperidone was purified by conversion to the hydrochloride, which was recrystallized twice from acetone and then decomposed with 30% alkali solution cooled to 0°. The free base was extracted with ether, dried with sodium sulfate and fractionally distilled in vacuum. The pure

1-carboethoxymethyl-2,5-dimethyl-4-piperidone obtained in this manner had b.p. 110.5-111° (1.5 mm).

n_D^{21} 1.4557, d_4^{21} 1.024, MR 56.40; Calc. 56.39.

After a short period the product crystallized completely to colorless crystals with m.p. 26-27°.

Found %: N 6.78, 6.73. $C_{11}H_{19}O_3N$. Calculated %: N 6.57.

Hydrochloride: m.p. 162.5-163° (from acetone), readily soluble in water and alcohol, less soluble in acetone.

Found %: Cl 14.45, 14.33. $C_{11}H_{20}O_3NCl$. Calculated %: Cl 14.23.

Treatment of 1-carboethoxymethyl-2,5-dimethyl-4-piperidone with an alcoholic solution of hydroxylamine hydrochloride gave the hydrochloride of the oxime with m.p. 171.5-172° (from alcohol).

Found %: N 10.47, 10.43; Cl 13.40. $C_{11}H_{21}O_3N_2Cl$. Calculated %: N 10.34; Cl 13.25.

Picrate: m.p. 139.5-140° (from alcohol).

1-α-Carboethoxyethyl-2,5-dimethyl-4-piperidone (III). A mixture of 9 g ethyl α-bromopropionate (b.p. 158-160°) and 13.3 g 2,5-dimethyl-4-piperidone was stood for 48 hours at room temperature, after which it was heated for 8 hours at 60°. The product was worked up in the usual manner to give 6.8 g (60% reckoned on the ethyl bromopropionate) of 1-α-carboethoxyethyl-2,5-dimethyl-4-piperidone.

B.p. 123-126° (3 mm), n_D^{18} 1.4652, d_4^{18} 1.027, MR 61.11; Calc. 61.02.

Found %: N 6.10, 6.13. $C_{12}H_{21}O_3N$. Calculated %: N 6.18.

Picrate: m.p. 162-162.5° after three recrystallizations from a 1:2 mixture of acetone and alcohol.

Found %: N 12.14. $C_{18}H_{23}O_{10}N_4$. Calculated %: N 12.28.

1-α-Carboethoxypropyl-2,5-dimethyl-4-piperidone (IV). A mixture of 26 g ethyl α-bromobutyrate (b.p. 177-179°) and 34 g 2,5-dimethyl-4-piperidone was stood 72 hours at room temperature, after which it was heated 10 hours at 60°. Crystals of the hydrobromide of the original piperidone came down. The reaction mass was worked up as usual and gave 11.6 g (36% reckoned on the bromoethyl butyrate taken into reaction) of 1-α-carboethoxypropyl-2,5-dimethyl-4-piperidone.

B.p. 128-131° (4 mm), n_D^{19} 1.4695, d_4^{19} 1.026, MR 65.48; Calc. 65.64.

Found %: N 5.51, 5.70. $C_{13}H_{23}O_3N$. Calculated %: N 5.80.

1-Carboxymethyl-2,5-dimethyl-4-piperidone (V). A mixture of 8.2 g bromoacetic acid, 15 g 2,5-dimethyl-4-piperidone and 20 ml dioxane was stood for 24 hours at room temperature and heated for 7 hours at 60°. After distillation of the dioxane, the vitreous mass was treated with 50 ml chloroform, the hydrobromide of the original piperidone was separated, and the mother liquor was evaporated to half its volume in vacuum and cooled. The resultant voluminous precipitate of 1-carboxymethyl-2,5-dimethyl-4-piperidone was filtered off, washed with hot anhydrous alcohol and recrystallized twice from 96% alcohol. A Beilstein test showed the absence of traces of bromine from the preparation. Yield 9.6 g 1-carboxymethyl-2,5-dimethyl-4-piperidone in the form of fine colorless crystals with m.p. 117-118°, soluble in water, aqueous alcohol and chloroform, poorly soluble in anhydrous alcohol, insoluble in ether.

Found %: N 7.25, 7.41. $C_9H_{15}O_3N$. Calculated %: N 7.58.

Picrate: m.p. 157-157.5° (from alcohol).

1-β-Carbomethoxyethyl-2,5-dimethyl-4-piperidone (VI). A mixture of 10 g 2,5-dimethyl-4-piperidone with 7.7 g methyl acrylate (b.p. 77-80°) was stood for 24 hours at room temperature and then heated for 8 hours at 110-120°. Fractional distillation in vacuum gave 10.6 g of 1-β-carbomethoxyethyl-2,5-dimethyl-4-piperidone in the form of a colorless, viscous liquid which turned yellow on standing.

B.p. 108-109° (2 mm); n_D^{20} 1.4719, d_4^{20} 1.0520, MR 56.67; Calc. 56.28.

Found %: C 62.19. 61.73; H 8.86, 8.66; N 6.79, 7.09. $C_{11}H_{19}O_3N$. Calculated %: C 61.85; H 8.92; N 6.65.

3.5 g of the original 2,5-dimethyl-4-piperidone was also isolated. The resinous residue weighed 1.5 g. Yield 63% on the 2,5-dimethyl-4-piperidone brought into the reaction and 96% on the actually reacted piperidone.

Hydrochloride: m.p. 164-165° (from acetone); readily soluble in water, alcohol and acetone, insoluble in ether.

Found %: Cl 14.10, 14.25. $C_{11}H_{20}O_3NCl$. Calculated %: Cl 14.20.

Picrate: m.p. 155-156°; soluble in acetone, poorly soluble in alcohol.

1-β-Cyanoethyl-2,5-dimethyl-4-piperidone (VII). A mixture of 20 g of 2,5-dimethyl-4-piperidone with 20 g acrylonitrile (b.p. 76-78°) was heated 10 hours at 115° and immediately afterwards distilled in vacuum. Yield 16 g (56% reckoned on the piperidone taken in the reaction) of 1-β-cyanoethyl-2,5-dimethyl-4-piperidone in the form of a light-yellow, viscous liquid.

B.p. 124-126° (2 mm), n_D^{20} 1.4842.

Found %: N 15.30, 15.50. $C_{10}H_{16}ON_2$. Calculated %: N 15.45.

In addition 8 g of the original acrylonitrile and 7.5 g of the 2,5-dimethyl-4-piperidone were recovered. Resinous residue 1 g.

Hydrochloride: m.p. 166.5-167° (from acetone).

Found %: Cl 16.30, 16.25. $C_{10}H_{17}ON_2Cl$. Calculated %: Cl 16.39.

Picrate: m.p. 136-137°; readily soluble in acetone, poorly in alcohol.

1-β-Propanal-2,5-dimethyl-4-piperidone (VIII). The experiment was performed in a nitrogen stream. To 10 g 2,5-dimethyl-4-piperidone in 40 ml acetone was added 10 g of freshly distilled acrolein which had been stabilized with hydroquinone. During the addition the liquid was continuously stirred and cooled with iced water. The reaction mass was stirred at room temperature for 9 hours and then immediately fractionally distilled in vacuum in a nitrogen stream. Yield 3.8 g 1-β-propanal-2,5-dimethyl-4-piperidone in the form of a light-yellow, viscous liquid which rapidly polymerized on standing in the air.

B.p. 81-82° (3 mm), n_D^{20} 1.4819.

Found %: N 8.50, 8.24. $C_{10}H_{17}O_2N$. Calculated %: N 7.26.

Picrate: m.p. 154-155° (from alcohol).

Found %: N 13.65, 13.63. $C_{16}H_{20}O_9N_4$. Calculated %: N 13.59.

Hydrochloride: a flocculent, highly hygroscopic substance which froths on melting at about 95°.

SUMMARY

A series of 1-carbalkoxyalkyl-2,5-dimethyl-4-piperidones was prepared. It was shown that 4-piperidonecarboxylic acids and their derivatives can be quite readily prepared by the following three methods: a) by the action on secondary (not substituted at the nitrogen) 4-piperidones of α-halo-substituted acids or their esters; b) by cyclization of dienones with the help of esters of amino acids; and c) by the addition of 4-piperidones to esters or other derivatives of α,β-unsaturated acids.

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FROM THE COMMITTEE ON CHEMICAL THERMODYNAMICS AT THE DIVISION OF CHEMICAL SCIENCE OF THE ACADEMY OF SCIENCES OF THE USSR

INFORMATION FOR SCIENTISTS DOING RESEARCH IN THE FIELD OF EXPERIMENTAL THERMOCHEMISTRY

The Subcommittee on Thermochemistry of the International Union on Pure and Applied Chemistry (IUPAC) in 1955 began to publish special issues, having small circulation, of the "Thermochemical bulletin" which contain short annotations on completed or soon to be completed work in the field of experimental thermochemistry in laboratories of various countries of the world. The division of chemical sciences of the Academy of Sciences of the USSR has received from IUPAC the second edition of this bulletin, which was published in March 1956 and has also received an invitation for all thermochemists of the USSR to take an interest in the publishing of this bulletin by announcing in it annotations on their works. The division of chemical sciences of the Academy of Sciences of the USSR accepted this invitation.

Upon the recommendation of the division of chemical sciences, the committee on chemical thermodynamics requests that all scientists who carry on research work send in, for announcement in the bulletin, short annotations on recently completed but not yet announced works with a short summary on methods used and results obtained; also subject matter intended for research or research being carried out at present can be announced. All material sent in for publication has to have the approval of the heads of department.

All materials for the thermochemical bulletin should be forwarded to the the following address: Professor S. M. Skuratovy, Chemical Faculty of the V. F. Luginina Thermochemical Laboratory, V 234 Leninskie gory, Moscow. The committee is taking steps to increase the number of copies of the thermochemical bulletin and to distribute them to scientific institutes of the Soviet Union.

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